

INFORMATION TO USERS

This manuscript has been reproduced from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps.

Photographs included in the original manuscript have been reproduced xerographically in this copy. Higher quality 6" x 9" black and white photographic prints are available for any photographs or illustrations appearing in this copy for an additional charge. Contact UMI directly to order.

**ProQuest Information and Learning
300 North Zeeb Road, Ann Arbor, MI 48106-1346 USA
800-521-0600**

UMI[®]

BUILDING THE SWEEPER MAGNET FOCAL PLANE DETECTOR

By

Christopher Ian Freigang

A THESIS

**Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of**

MASTER OF SCIENCE

Department of Physics and Astronomy

2001

UMI Number: 1405934

UMI[®]

UMI Microform 1405934

Copyright 2001 by Bell & Howell Information and Learning Company.

**All rights reserved. This microform edition is protected against
unauthorized copying under Title 17, United States Code.**

**Bell & Howell Information and Learning Company
300 North Zeeb Road
P.O. Box 1346
Ann Arbor, MI 48106-1346**

ABSTRACT

BUILDING THE SWEEPER MAGNET FOCAL PLANE DETECTOR

By

Christopher Ian Freigang

This document provides an overview of the sweeper magnet focal plane detector components and guidance on its assembly.

Acknowledgements

“Est unusquisque faber ipsae suae fortunae”

Appius Claudius

First and foremost I would to thank **Michael Thoennesen** for his leadership guidance and support in all aspects of my time here. In addition I would like to thank **John Yurkon, Craig Snow, Daniel Bazin, Len Morris, Thomas Baumann, and Jim Vincent** for their knowledge, experience, and assistance in this project. Finally I would like to thank **Ryan Clement, Gene Flanagan, Patrick Lofy, Paul Heckman** and a litany of others, for their friendship, support, and wit their day-to-day levity that always brought a smile to my face.

Semper Fi!

“Acta est fibula”

Imperator C. Iulius Caesar Octavianus Augustus

Table of Contents

List of Figures.....	v
List of Tables.....	vii
1 The Focal Plane Detector.....	1
2 Mechanical System.....	3
2.1 The vacuum box.....	3
2.2 Moving the vacuum box.....	3
2.3 Vacuum box support frame.....	4
2.4 Rail system.....	4
2.5 Detector trolleys.....	5
2.6 Cables gas and cooling lines.....	7
2.7 Rotary pneumatic actuators.....	8
2.8 Vacuum box feedthroughs.....	8
2.9 Access panels.....	10
2.9.1 Top access panels.....	10
2.9.2 Side access panels.....	10
3 Support Systems.....	12
3.1 Platform.....	12
3.2 Pneumatic service.....	12
3.3 Electrical service.....	13
3.4 Power backup.....	13
3.5 Patch panels.....	14
3.6 Network hub.....	14
3.7 Modicon-PLC panel.....	14
3.8 Instrument racks.....	14

4	The Cooling System	15
4.1	Overview.....	15
4.2	Insulation.....	15
4.3	Heat sinks.....	16
4.4	Manifolds.....	17
4.5	Hose.....	17
4.6	Control panel.....	18
5	The Gas System	19
5.1	The vacuum system.....	19
5.2	The gas handling system.....	20
5.2.1	Overview.....	20
5.2.2	Gas supply.....	21
5.2.3	Tubing and hose.....	21
5.2.4	Gas handling system control box.....	22
5.2.5	Gas Flow in the Detectors.....	24
5.2.6	Roughing pumps.....	24
6	Detection System	25
6.1	Overview.....	25
6.2	Geometry.....	26
6.3	Cathode Readout Drift Chamber	27
6.3.1	Overview.....	27
6.3.2	Printed circuit board assembly.....	28
6.3.3	Window assembly.....	29
6.3.4	Anode frame assembly.....	30
6.3.5	CRDC assembly.....	32
6.4	Frisch Gridded Ion Chamber	34
6.4.1	Overview.....	34
6.4.2	Ion chamber box.....	34
6.4.3	Ion chamber assembly.....	35

6.5 Organic scintillators.....	38
6.5.1 Overview.....	38
6.5.2 Photo multiplier tubes.....	39
6.5.3 Assembly.....	40
7 Data Acquisition System.....	41
7.1 Overview.....	41
7.2 Operation.....	41
7.3 CRDC data acquisition.....	42
7.4 Ion chamber data acquisition.....	44
7.5 Scintillator data acquisition.....	44
7.6 Instrument crates.....	45
7.7 Low voltage power supplies.....	45
7.8 Definitions.....	46
8 Control and Monitoring System.....	47
8.1 Overview.....	47
8.2 Modicon-PLC.....	48
8.3 Software.....	48
8.4 Vacuum system control and monitoring.....	49
8.5 Mass flow controllers and Baratron pressure transducers.....	50
8.6 Solenoid controlled pneumatically operated diaphragm valves.....	51
8.7 Detector and heat sink monitoring.....	51
8.8 Roughing pumps and valve Sentries.....	51
8.9 Calibration mask motion control.....	53
8.10 Power supplies.....	53
8.11 Interlocks.....	53
9 Summary.....	54

List of Figures

1.1	Layout of the N-4 experimental vault. The quadrupole triplet can be seen sitting in front of the Sweeper Magnet.....	2
1.2	A three dimensional view of the Sweeper Magnet. A beam consisting of the projectiles and fragments enters the magnet. The charged fragments are swept away from zero degrees into the focal plane detector.....	2
2.1	The focal plane detector at its normal position of 40°.....	4
2.2	At 23° the focal plane detector is at its minimum angle from the zero degree axis.....	4
2.3	A view of the rail system. The short rail allows the detectors to use the full length of the Vacuum Box. This detector trolley can have its cam rollers extended so it can use the north rail.....	5
2.4	A side view of the CIS group.....	6
2.5	This view shows the cam roller assembly. (A) is the position for the short rail, and (B) is the position for the north rail. (See figure 4.2) The three bolts are removed and the cam roller assembly is moved to the other side of the trolley leg.....	7
2.6	End on view of CRDC-1 mask drive assembly. CRDC-2 drive assembly is identical but driven from the east side of the box.....	8
2.7	North side of the focal plane detector looking south.....	10
2.8	South side of the focal plane detector looking north.....	11
3.1	Proposed layout of the focal plane detector area in the N-4 experimental vault.....	12
3.2	Schematic of the focal plane detector pneumatic service.....	13
4.1	Schematic of the FEE heat sink.....	16
5.1	View of the gas system section of the detector.....	20
5.2	Layout of the gas handling system and sub-systems.....	21

6.1	An internal view of the focal plane detector showing the layout of the detectors. The rail system allows for CRDC-1 and the CIS group to move independently allowing the detector system multiple configurations.....	25
6.2	A simplified view of the interior of the Vacuum Box. Note that the CRDCs are rotated 180°	26
6.3	Top view of the focal plane detector showing the detector system layout.....	27
6.4	A dramatized view of the operation of a CRDC. The gas is ionized as the ion passes through the detector the disassociated electrons drift towards the anode wire where the charge is collected. An induced charge is created on cathode pads by this collection and provides the x position of the charged particle track. The drift time of the electrons to the anode wire provides the y position of the charge particle track. A Frisch Grid is used to remove dependence of the pulse amplitude on position of interaction with detector gas.....	28
6.5	A close up view of a PCB this shows the high voltage trace that will be covered with a strip of G-10 to prevent sparking. To the left is the field shaping strips, and on top the cathode pads.....	29
6.6	Cross-section of the CRDC Window Frame. Each frame has four ports that can be configured for a pressure, temperature, transducer or gas in/out depending on which CRDC.....	31
6.7	One window frame differs from the others by being reversible by having "O" ring grooves on both sides. This view shows the location of the reversible window frame.....	31
6.8	The left figure shows the location of the anode wire, Frisch grid and cathode-grounding plane. The figure on the right shows the location of the copper bar and wire insulator.....	32
6.9	Exploded view of a CRDC. The G-10 spacers are laminated to the printed circuit boards with TRA-Bond F-113 epoxy. This provides a good "O" ring seal between the PCB, window frame, and anode frame. The electrical connection is made between both PCBs with the 34-pin ribbon cable connectors.....	34
6.10	An end-on view of the CRDC assembly.....	34
6.11	This figure shows the operation of a single pad in the ion chamber. The electrons are collected on the upper plate, creating an increase in voltage across the resistor. This is what we see as a signal. The Frisch grid removes amplitude dependence position.....	35

6.10	A three dimensional view of the ion chamber's components and assembly.....	38
6.5	Side view of the Ion Chambers' assembly.....	38
6.12	Trigger scintillator dimensions. Note the "fish tail" lightguides.....	40
6.13	Stopping scintillator dimensions.....	40
7.1	Data acquisition layout. All network communication will be done with TCP/IP.....	42
7.2	Schematic of the CRDC data acquisition electronics. Only one of the CRDC's is represented here.....	43
7.3	This describes the operation of the CRDC Front End Electronics (FEE) for a single cathode pad. Each CRDC has three boards with 32 channels and one with 20. There are a total of 116 channels per CRDC.....	43
7.4	CRDC anode wire preamplifier circuit. Each CRDC has one located as close as possible to the anode wire to minimize noise.....	43
7.5	Schematic of the ion chamber data acquisition electronics.....	44
7.6	Schematic of the data acquisition electronics for both the trigger scintillator and the stopping scintillator. This figure only represents two photo multiplier tubes. Each scintillator has four PMTs'.....	45
8.1	A layout of the control and monitoring system. Detector status information necessary can be archived.....	47
8.2	This figure represents a temperature transducer shunt circuit; there are 11 of them. Variable resistors are used for calibration and all use the same power supply. The output voltage signal is sent to an ADC, then to the Modicon-PLC where is read by the process control software.....	52

List of Tables

2.1	Feedthrough specifications.....	9
4.1	Chiller Unit specifications.....	15
4.2	Hose specifications.....	17
5.1	Tube and hose specifications.....	22
6.1	CRDC specifications.....	28
6.2	Ion chamber specifications.....	34
6.3	Scintillator specifications.....	38
6.4	PMT Specifications.....	39
8.1	MFCs' and BACMs' specifications.....	50

Chapter 1

The Focal Plane Detector

The upgrading of the National Superconducting Cyclotron Laboratory resulted in an increase in types and intensities of radioactive beams available at the NSCL. A need arose to develop a detection system to utilize the new capabilities. To take advantage of these new beams, a sweeper magnet will be built (Figure 1.1).

The sweeper magnet will be a 4 Tesla highly compact "C" magnet made with superconducting coils with a bend angle of 40° . Designed with maximum accessibility across the dispersive plane and low fringe fields, it is referred to as a "C" magnet design because all of the return yoke is located to one side. In the N-4 vault, the magnet will work as a broad range spectrometer and have two modes of operation: one in which a quadrupole triplet in front of the sweeper magnet will be used as a focusing element, and one without a quadrupole triplet.

Instrumented with a focal plan detector similar to the S-800 detection system, the sweeper magnet will be used to study neutron and proton rich nuclei by separating charged fragments from the neutrons (Figure 1.2). The focal plane detector (FPD) will be comprised of two (x and y direction) tracking detectors (CRDCs), an ion chamber for energy loss measurements, a thin organic scintillator used as an event trigger (the trigger scintillator), and a thick organic scintillator for energy determination (the stopping scintillator). The focal plane detector will use ray reconstruction to determine the momentum of the charged fragments that are swept out of the beam.

The purpose of this document is to provide an overview of the sweeper magnet focal plane detector components and guidance on its assembly.

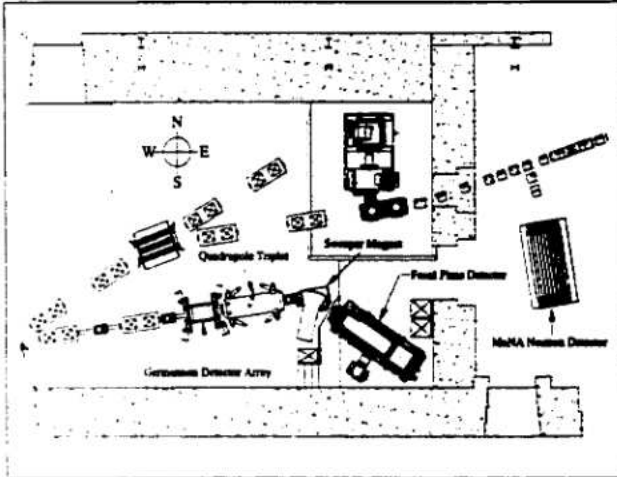


Figure 1.1: Layout of the N-4 experimental vault. The quadrupole triplet can be seen sitting in front of the Sweeper Magnet.

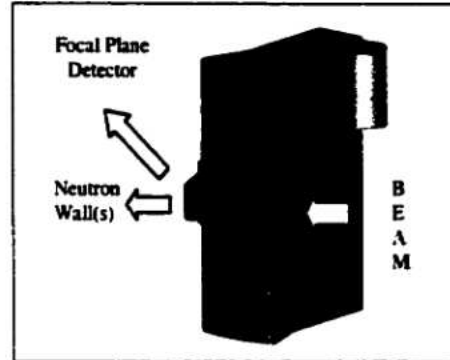


Figure 1.2: A three dimensional view of the Sweeper Magnet. A beam consisting of the projectiles and fragments enters the magnet. The charged fragments are swept away from zero degrees into the focal plane detector.

Chapter 2

Mechanical Systems

2.1 The Vacuum Box

The vacuum box (VB) is the largest component of the detection system. It is designed to maintain the vacuum in which the three detectors reside. The box will be constructed of welded 304 stainless steel plates; have an internal volume of 3.39 m³, and weighs 3.3 tons.

Charged particles will enter the west end of the detector through an ISO 250 flange. This flange limits the beam extent to 25 cm.

2.2 Moving the Vacuum Box

The northwest edge of the vacuum box will be cut at 12°. This allows the box to be moved from its normal position of 40° to a minimum of 23° without interfering with the neutron flight path (Figure 2.1 and 2.2). Lifting the box with a hoist, then moving it to the new position changes the angle. A new aperture plate specific to that angle couples the sweeper magnet to the focal plane detector.

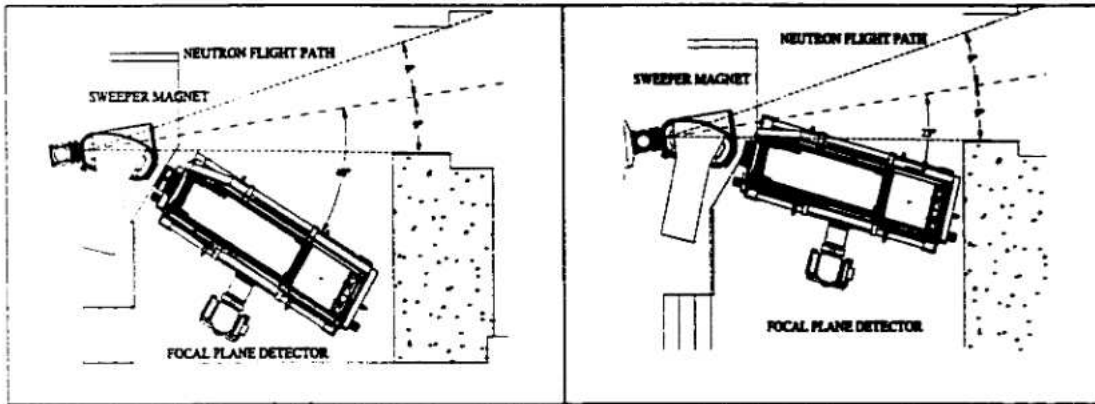


Figure 2.1: The focal plane detector at its normal position of 40°.

Figure 2.2: At 23° the focal plane detector is at its minimum angle from the zero degree axes.

2.3 Vacuum Box Support Frame

The vacuum box support frame allows adjustments in the box's alignment to be made for coupling to the sweeper magnet. The box, sitting freely on the support, can have its height adjusted by the extension or contraction of any of its 4 feet. Or the box can move horizontally by the extension or contraction of any of the 6 support pads around the base of the box.

2.4 Rail System

The vacuum box will have an internal rail system to support the three detectors and allow the detectors' positions to change along the beam axis.

The box will have three rails. The one on the south side will have a "V" groove and will run the full length of the box. The other two are on the north side. The north rail runs from the cut in the box to the east side. The shorter one (Short rail) is designed to allow the detectors to move the full length of the box, past the 12° cut (Figure 2.3).

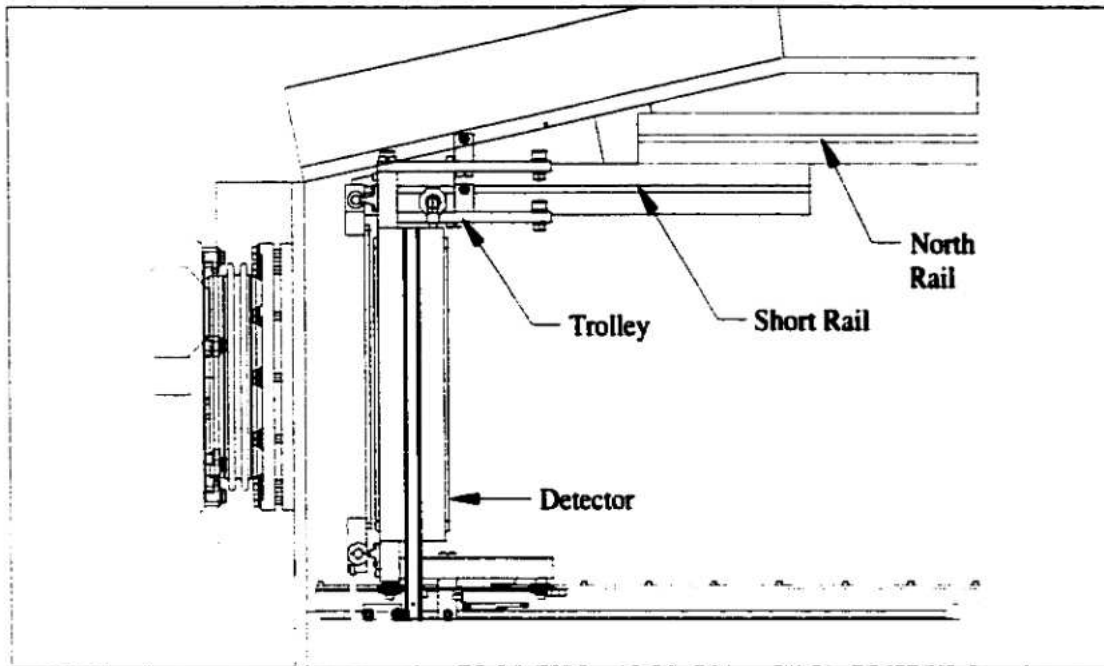


Figure 2.3: View of the rail system. The short rail allows the detectors to use the full length of the Vacuum Box. This detector trolley can have its cam rollers extended so it can use the north rail.

2.5 Detector Trolleys

There are two detector trolleys in the focal plane detector, one for the first CRDC (CRDC-1), and the other for the second CRDC (CRDC-2), Ion Chamber, and Scintillator group (CIS) (Figure 2.4).

Each trolley uses four cam rollers. The rollers on the south side are “V” grooved to provide direction when the trolley moves; the others on the north side are flat faced.

The trolleys are made of aluminum, and in addition to the detectors they carry the CRDC position calibration mask assemblies. Attached to each trolley are 2 hose clips for the detector gas supply, two distribution manifolds for coolant, and the CRDC anode wire preamplifier box.

To use the short rail CRDC-1's trolley wheelbase can be changed. This is done by removing three bolts, moving the cam roller assembly, then moving the assembly to the other side of the trolley leg, and finally reinstalling the three bolts (Figure 2.3)

Once the detector is in position, bolts attached to the cam assembly extend to prevent movement (Figure 2.3).

The rail system will have a measuring tape along the south side, so that the position of the detector can be determined.

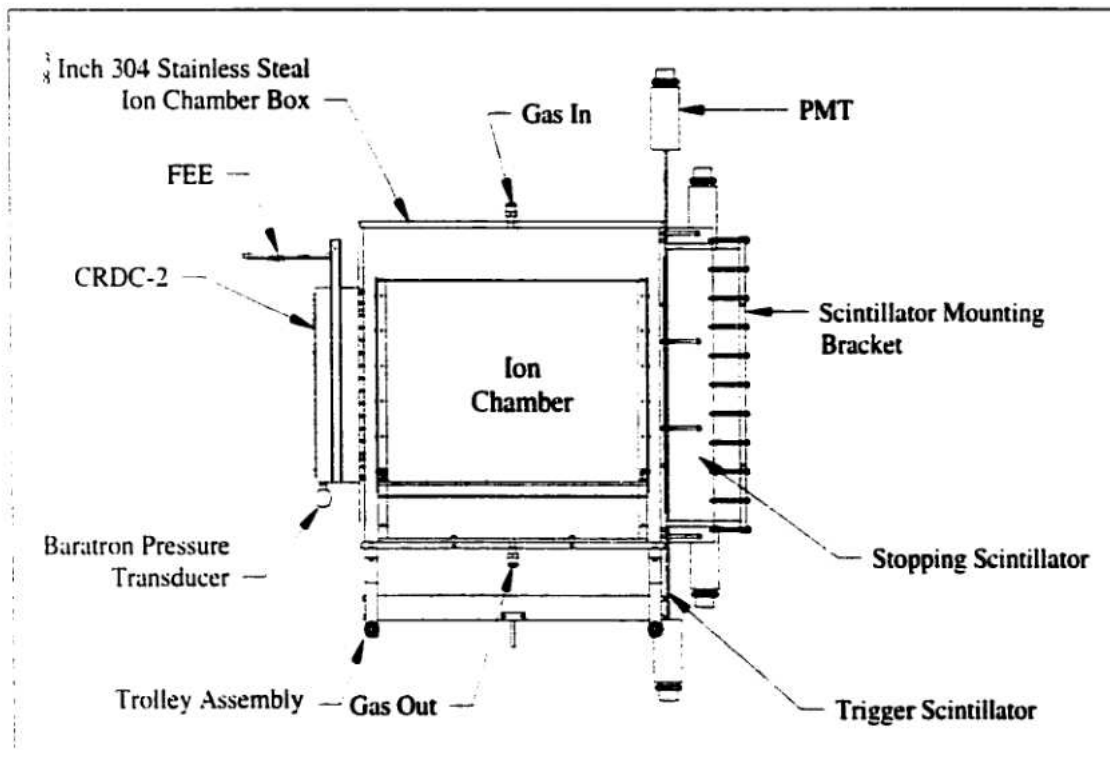


Figure 2.4: A side view of the CIS group.

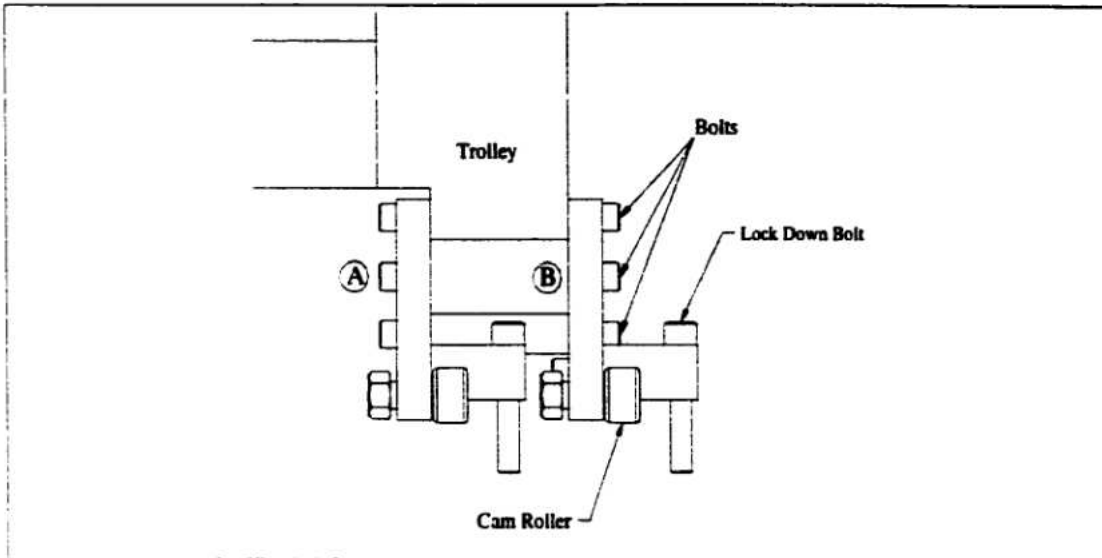


Figure 2.5: This view shows the cam roller assembly, (A) is the position for the short rail, and (B) is the position for the north rail. The three bolts are removed and the cam roller assembly is moved to the other side of the trolley leg.

2.6 Cables Gas And Cooling Lines

The vacuum box has a “cable race” at the bottom for the routing of the extra long cables, cooling, and gas lines needed to allow the detectors to move freely over the length of the box.

2.7 Rotary Pneumatic Actuators

A system has been designed to allow both CRDCs a change position while still having the ability to perform position calibrations remotely. Two pneumatically driven rotary actuators located outside the vacuum box turn drive shafts attached to the mask assemblies, raising and lowering the masks (Figure 2.6).

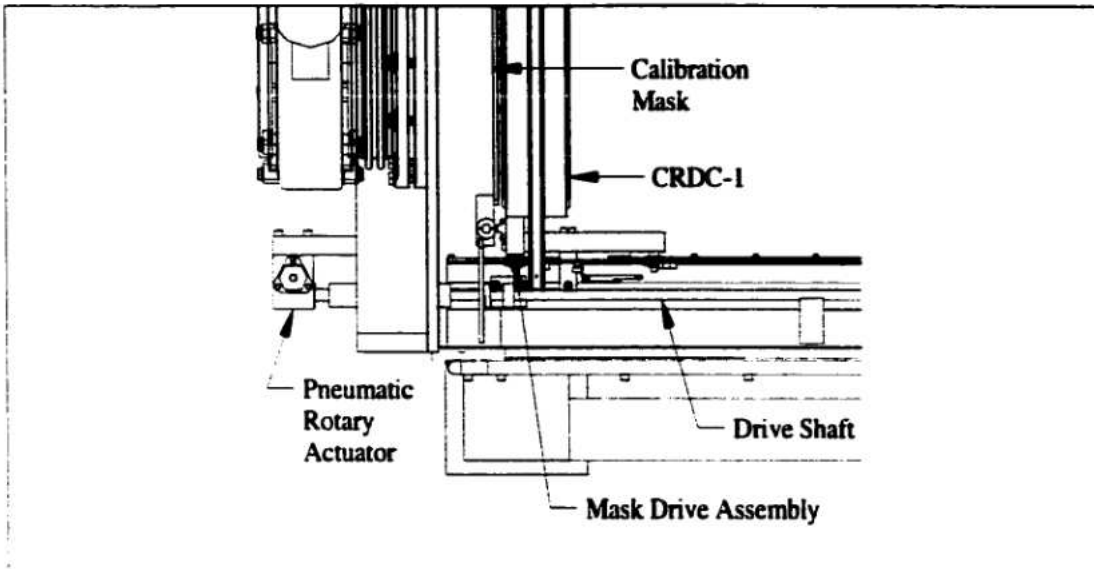


Figure 2.6: End on view of CRDC-1 mask drive assembly. CRDC-2 drive assembly is identical but driven from the east side of the box.

2.8 The Vacuum Box Feedthroughs

There are thirteen ports in the vacuum box: 11 are dedicated feedthroughs one will be for the vacuum pump, and the last one for the entrance flange. Of the eleven, 6 are ISO 250 located around the base of the vacuum box: two on the north side, two on the south side, and two on the east side. The remaining five are KF-25 flanges located around the turbo-roughing pump inlet flange (south side middle of the detector box).

The feedthroughs can be broken down into three categories: electrical, mechanical, and vacuum (the KF-25 and feedthroughs and two vacuum ports uses will be discussed in section 5.1). Of the six ISO 250 flanges, one will be dedicated to the CRDCs electronics and another to the ion chamber electronics. These flanges are custom designed and are made of G-10 phenolic board with thirteen thirty-four pin ribbon cable connectors. The G-10 boards are compressed between two bored ISO 250 blanks with a Viton "O" ring giving it a vacuum seal.

A flange is dedicated to mechanical systems: coolant in and out for the CRDC front-end electronics (FEE) (Discussed in chapter 4), and detector gas in/out (Discussed in chapter 5). This flange should be located at one of the two ports below the gas handling system control box (Figure 2.7).

The two remaining feedthroughs will have 20 BNC and 20 SHV connectors, 10 on each flange. One will be located on the north side and the other on the south side. The last feedthrough will have: the temperature transducers' thirty-four-pin ribbon cable connector, three nine-pin connectors for the pressure transducers, and eight nine-pin connectors for the PMT bases.

Table 2.1: Feedthrough Specifications

Flange #	TYPE	Feedthrough/Port
1	ISO 250	1 x Custom G-10 feedthroughs 13 34 pin connectors (Ion Chamber)
2	ISO 250	1 x Custom G-10 feedthroughs 13 34 pin connectors (CRDC's)
3	ISO 250	6 x VCR-6 female connectors 2 x 1/4" vacuum insulated coolant feedthroughs
4	ISO 250	10 x BNC 10 x SHV
5	ISO 250	10 x BNC 10 x SHV
6	ISO 250	1 x 34 pin connector (Temperature Transducers) 3 x 9 pin connectors (Pressure Transducers) 8 x 9 pin connectors (PMT bases)
7	KF-16	1 x Convection enhanced Pirani gauge
8	KF-16	1 x Ionization gauge
9	KF-16	Blank
10	KF-16	Blank
11	KF-16	Blank
12	ISO 250	Beam line port
13	ISO 250	Turbo Roughing pump port

2.6 Access Panels

The vacuum box has four access panels: two on the south side, one on the north side, and one on the top.

The access panel on the top will be used for placing into and removing equipment too large and or too heavy to be removed through the side panels. Since the top access panel is used infrequently, it has no hinges, and will be sealed with a Viton "O" ring, then bolted into place. When access is required the panel will be lifted with a hoist.

2.9.2 Side Access Panel

The three side access panels differ from the top panel by being hinged for easy opening and closing. The side panels will also be bolted into place, and sealed with a Viton "O" ring.

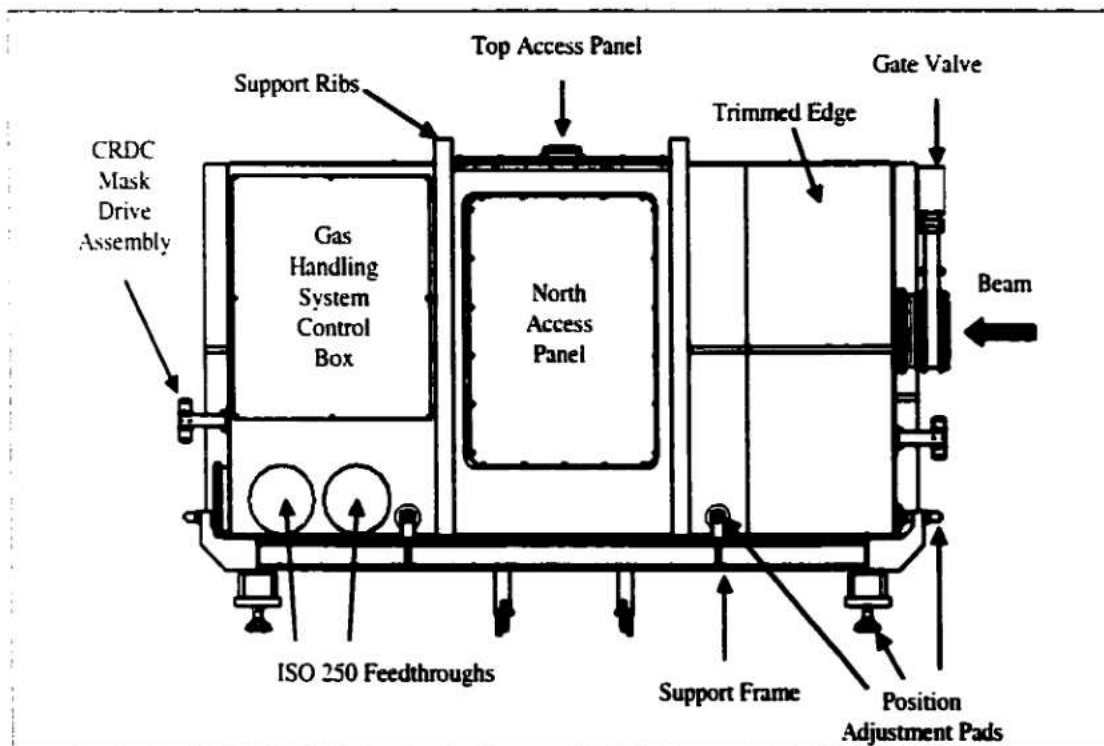


Figure 2.7: North side of the focal plane detector looking south.

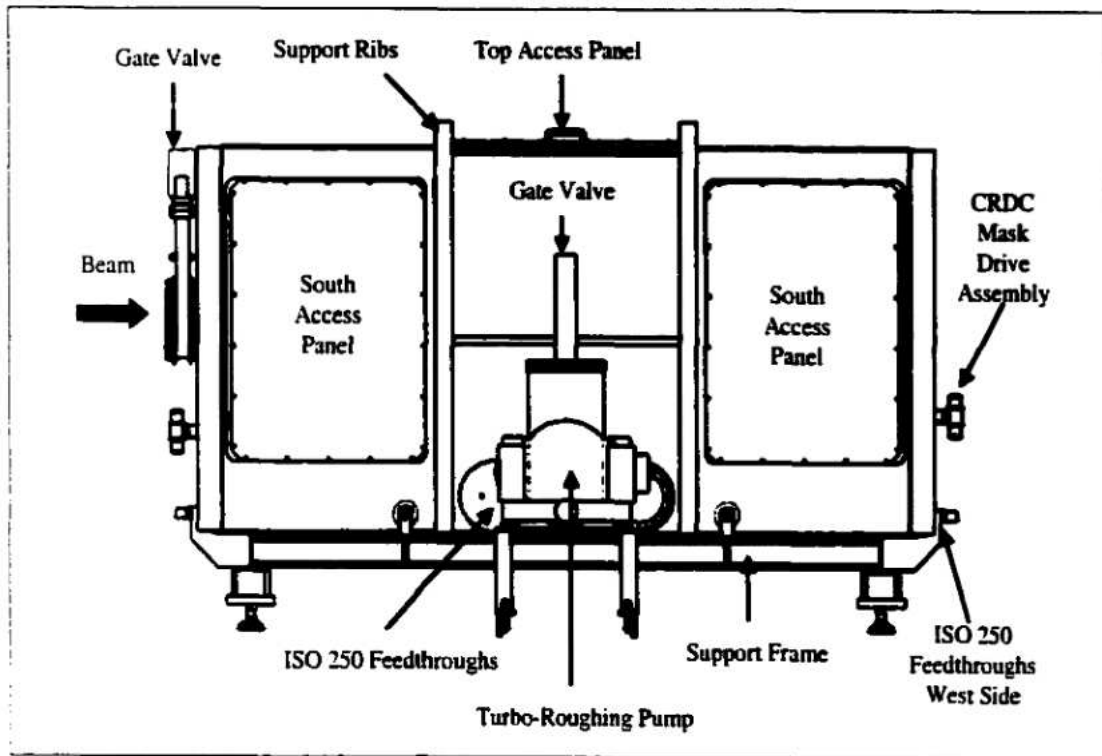


Figure 2.8: South side of the focal plane detector looking north.

Chapter 3

Support Systems

3.1 Platform

At the west side of the N-4 vault there is a step that rises 109.22 cm. The layout of the N-4 vault requires that the focal plane detector straddle that step. A steel platform and stairs have been designed to provide support for the vacuum box, as well as access on its south side. The platform will have a railing and an overhang to provide storage for the detector gases, tools, and equipment (Figure 3.1).

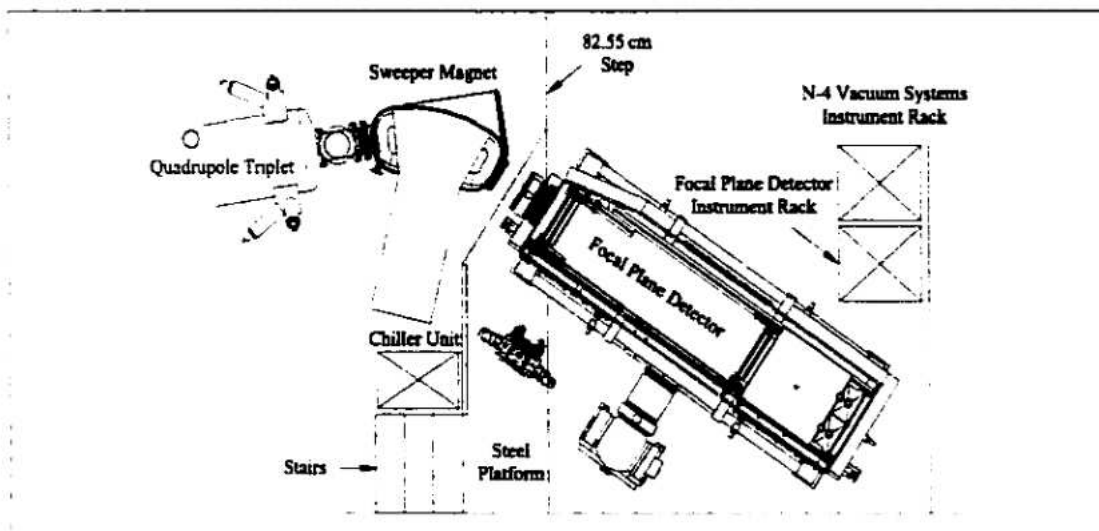


Figure 3.1: Proposed layout of the focal plane detector area in the N-4 experimental vault.

3.2 Pneumatic Service

The laboratory provides air service of 80 PSI to pneumatically operate experimental equipment in the N-4 vault. The Focal Plane Detector will have a dedicated line to operate: the pneumatic valves for the gas handling system, the rotary actuators, and the two gate valves. An outlet with a master shutoff, trap, and filter, will be provided

along the south wall of the N-4 vault next to the detector. A supply line will deliver the air from the outlet to the distribution manifold and control panel and will be located next to the gas handling system control box (Figure 3.2).

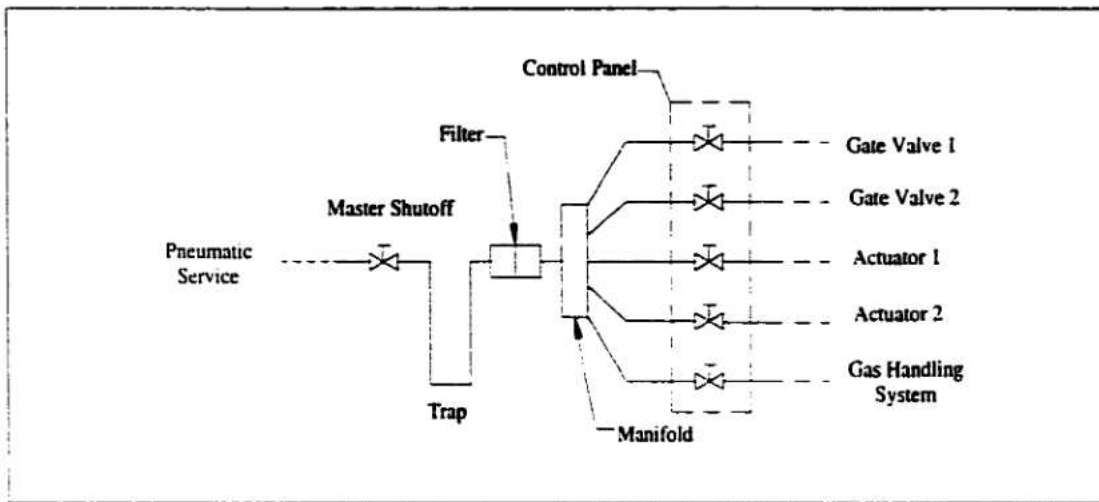


Figure 3.2: Schematic of the focal plane detector pneumatic service.

3.3 Electrical Service

To provide power for the focal plane detector equipment, 4 quad boxes of 120V 60Hz single-phase and a dedicated 208V 60Hz single-phase outlet (the 208V 60Hz single phase is used for the turbo-roughing pump controller) will be installed. Three of the quad boxes will be “dirty power” and one will be “clean power”. The outlets will be located on the south wall near the detector in a gang box.

3.4 Power Backup

An uninterruptible power supply (UPS) will be installed in the FPD instrument rack. The UPS will allow the principal systems to be stabilized and shut down safely in the event of a power failure. Principal systems include, the Data Acquisition System (DAQ), the Control System (CS), and the Gas Handling System (GHS).

3.5 Patch Panels

The Focal Plane Detector will share a patch panel with the Apex-Germanium array. The panel will be located midway between the two systems on the south wall of the N-4 vault. The panel will support 10 SHV and 10 BNC connectors, and will be connected to a mirror panel in the "data U" N-4 station.

3.6 Network Hub

An Ether Net network hub with 8 channels will be located along the south wall of N-4 vault. The FPD will need three of these Ether Net connections: one for the control IBM/PC, one for the data acquisition IBM/PC, and one for EPICS control.

3.7 Modicon-PLC Panel

The Modicon-PLC panel is located in the hallway running parallel to the north side of the N-4 vault. A phone block box and relay will be connected directly to the Modicon-PLC panel and will be located next to the FPD. Housed in the box will be the analogue to digital converter modules and Modicon-PLC coils.

3.8 Instrument Racks

There will be two standard relay racks (instrument racks) located in the FPD area. One is dedicated to the vacuum systems in the N-4 vault. The other relay rack will be dedicated to the FPD electronics. Both racks have the dimensions 200.66 cm x 64.77 cm x 60.96 cm.

Chapter 4

The Cooling System

4.1 Overview

The CRDC front-end electronics (FEE) boards reside in vacuum and will generate heat during operation. With no way to dissipate this heat the boards could suffer a loss in efficiency, and or damage. The FPD will be equipped with a dedicated cooling system to cool the boards. The system will consist of: eight heat sinks, one for each board, a re-circulating chiller, a control panel, distribution manifolds, and distribution tubing (a schematic of the cooling system is provided in appendix A)

Table 4.1: Chiller Unit Specifications

Temperature range	+5°C to + 35°C
Temperature stability	±0.1C°
Reservoir volume	1.9 l
Coolant	50/50 Uninhibited Ethylene Glycol/Water
Estimated cooling capacity at +5°C	500 Watts
Each Board Generates	1 Watt

4.2 Insulation

Two steps will be taken to prevent a reduction in the Cooling System efficiency. First, two liquid nitrogen tube welds (vacuum insulated 0.635 cm OD 304-SS) will be used as coolant feedthroughs, one for an inlet and the other for an outlet. They will be located in vacuum box ISO 250 mechanical feedthrough. To connect each tube to the

distribution hose they will have 0.635 cm butt weld to a 0.635 cm hose bard custom welded to them.

Second, 0.08 cm thick PTFE sheets cut to size will be placed between the manifolds and any non-conducting, non-cooling system components, insulating the manifolds.

4.3 Heat Sinks

Copper heat sinks will be used to cool the FEE boards. They will be mounted to the FEEs with screws, and independently supported by a bracket connected to the detector trolley. These brackets will allow for minor adjustment to be made to the position of the boards and heat sinks.

Coolant will enter and leave the heat sink through two brass 10-32 to 0.3175 cm ID hose barbs.

Separating the heat sinks and the FEE boards will be a "Gap Pad" 1500 0.3175 cm thick. Gap pad is a flexible thermally conducting material used to fill air gaps.

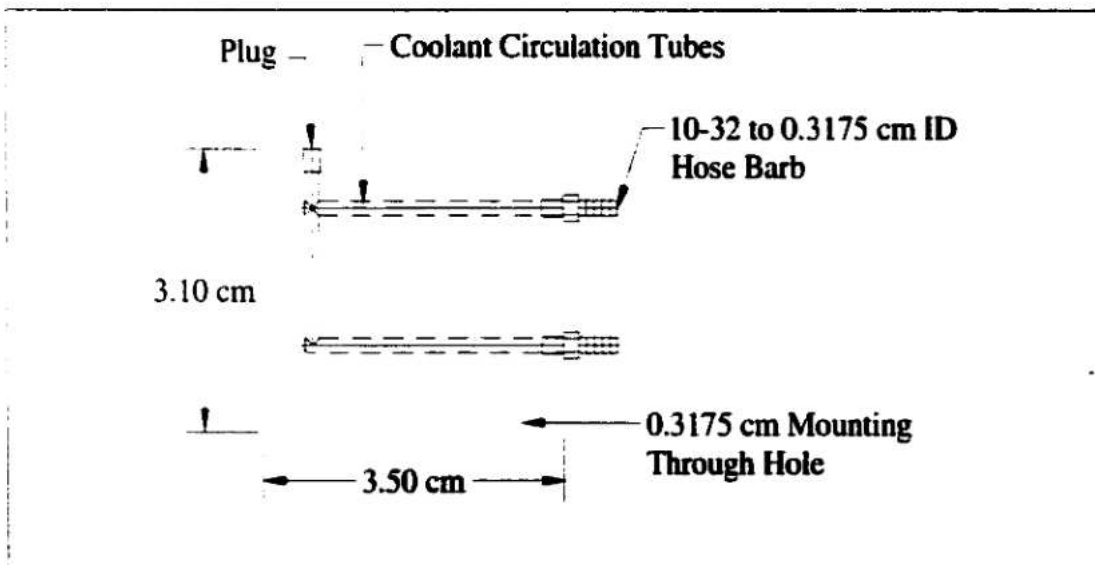


Figure 4.1: Schematic of the FEE heat sink

4.4 Manifolds

There are two types of manifolds in the cooling system, they are labeled 1st stage and 2nd stage, and both are made of brass.

The four 1st stage manifolds will be attached to the detector trolleys. The two 2nd stage manifolds will be mounted to the vacuum box near the mechanical feedthrough.

The 1st stage manifold has four 10-32 to 0.3175 cm hose barb, and one 0.3175 cm NPT to 0.635 cm hose barbs. The 2nd stage manifolds will have three 0.3175 cm NPT to 0.635 cm hose barbs. All hose barbs threads will use Teflon tape for a thread sealant.

4.5 Hose

There will be two types hose used in the Cooling System. From the 1st stage manifold to the heat sinks, 0.3175 cm ID 0.635 cm OD polyurethane hose is used. This hose is color coded to prevent the hoses from being attached to the heat sinks in the wrong order, blue for cool coolant in and red for warm coolant out.

The rest of the system uses a clear Dacron reinforced polyurethane hose 0.635 cm ID and 1.194 cm OD.

To prevent leaks all hoses will use stainless steel hose clamps to ensure a secure attachment to the hose barbs.

Table 4.2: Hose Specifications

Type Of Hose/Tubing Used	ID/OD
Polyurethane hose, reinforced with polyester and Dacron	.635/1.194 cm
Heavy walled Polyurethane hose blue/red	.3175/0.635 cm

4.6 Control Panel

It is suggested that the cooling system have a control panel with four PFA valves mounted on a insulating sheet. Two of the valves are for the warm and cold coolant supply and return. The other two are for purging the system of coolant. One valve will be connected to the pneumatic system, and the other will return coolant to the chiller coolant reservoir (See Appendix A).

Chapter 5

The Gas System

To protect systems from damage, the Focal Plane detector has been designed with an integrated gas system broken down into two parts. One is responsible for controlling the vacuum in the detector box. The other is made up of the physical infrastructure for detector gas delivery.

5.1 The Vacuum System

The vacuum system will be comprised of: a turbo-roughing pump, (composite unit) two gate valves, and two pressure transducers.

The turbo-roughing pump is an air-cooled 1900 l/min pump, responsible for achieving and maintaining the vacuum in the box. The pump will be attached to an ISO 250 flange connected to 25.4 cm long beam pipe. This beam pipe is in turn attached to the ISO 250 vacuum port flange in the vacuum box. This allows the pump to “stand off” from the box and allow access to the two south side access panels.

One of the two gate valves is used to isolate the turbo-roughing pump from the vacuum box, the other, the vacuum box from the upstream vacuum. Both gate valves are ISO 250 and are operated by pneumatically controlled solenoid valves.

Both pressure transducers will be attached to one of the KF-25 flanges that ring the ISO 250 vacuum port flange on the south side of the vacuum box (Figure 5.1).

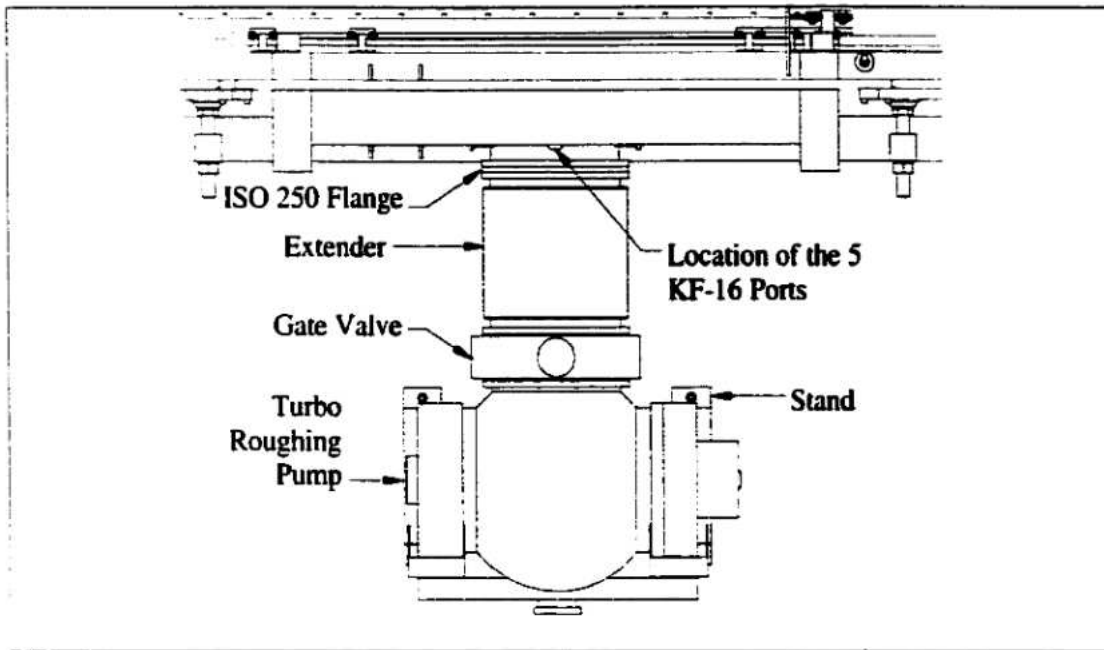


Figure 5.1: View of the gas system section of the detector.

5.2 The Gas Handling System

5.2.1 Overview

The focal plane detector has three gas detectors, two CRDCs and an ion chamber (IC). The gas handling system (GHS) is designed to be a high purity gas delivery system to deliver gas to the detectors. The system is made up of four components: gas supply, the gas handling system control box, the detectors, and the roughing pumps.

The GHS has two independent delivery systems for the two types of detectors in the FPD. Each detector type requires different gases. One of the delivery system is dedicated to the CRDCs and uses a combination of 80% CF_4 and 20% C_4H_{10} . The other is dedicated to the Ion Chamber (IC), and uses a premixed gas called P-10, P-10 is 80% Ar and 20% CH_4 .

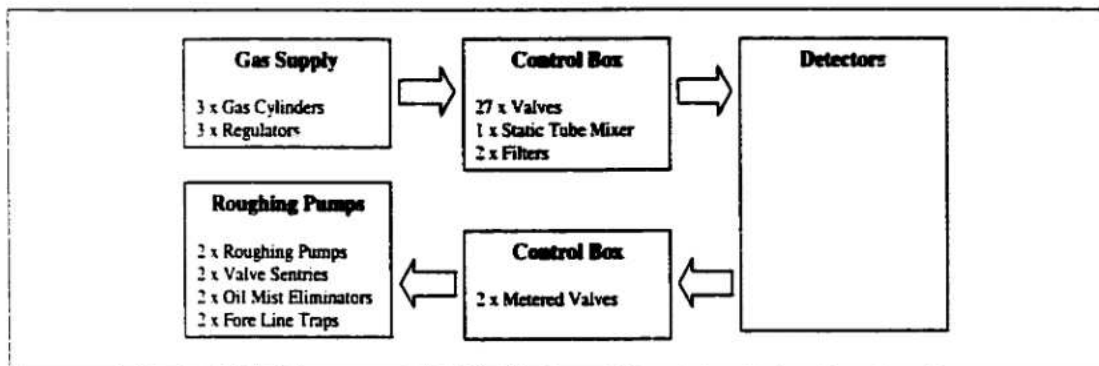


Figure 5.2: Layout of the Gas Handling System and sub-systems.

5.2.2 Gas Supply

Detector gases will be delivered to the GHS from the three gas supply cylinders (the gas cylinders will be located on or under the support platform in N-4). Two of the cylinders will use a two stage high purity brass regulators (for P-10 and CF₄). The other cylinder will use single stage a high purity brass regulator (for C₄ H₁₀). All the regulators are designed for non-corrosive gases and have two gauges that read high and low pressure. Each regulator will have a 5000 Torr 316-SS over pressure relief valve (The over-pressure relief valve is to protect equipment in the GHS for over pressurization). To make the connection to the rest of the GHS, this valve will have welded to it a 316-SS hose barb.

5.2.3 Tubing And Hose

There will be two types of hosing and one type of tube used in the GHS. The tubing used is electro-polished 316-SS and is exclusively used in the GHS control panel.

For gas distribution 1.27 cm ID hose is used. The distribution hose is used to: transfer the gas from the supply cylinders/regulators to the GHS control panel, GHS control panel to the vacuum box feedthroughs, from the vacuum box feedthroughs to the detectors, and back through the vacuum box feedthrough to the control box. This hose

also will be used for the vacuum connections between the control box and the two vacuum ports on the mechanical feedthrough flange (allowing the detectors and vacuum box to be pumped down at the same time). All connections are made with hose barbs custom welded to VCR-8 female adaptors. To ensure a leak-free fit, stainless steel hose clamps on both sides of the hose (necessary because the detectors move).

The last type of hose used is 2.54 cm ID 3.35 cm OD PVC wire reinforced vacuum hose. This hose will have two KF-25 tube welds and two stainless steel hose clamps on each end to provide the connections. Vacuum hose will be used between the GHS control box and the roughing pump fore line trap.

Table 5.1: Tube and Hose Specifications

Type Of Hose/Tubing Used	ID/OD	Use
Electro-polished 316 stainless steel tubing	1.27 cm/1.0 cm	Control Box
Polyurethane hose, reinforced with polyester and Dacron	1.27 cm/1.9 cm	Distribution
PVC wire reinforced hose	2.54 cm/3.35 cm	Roughing pumps to Control Panel

5.2.4 The Gas Handling System Control Box

The control box houses all the control mechanisms and some of the monitoring equipment used in the GHS. In the box there will be: three metal-sealed Mass Flow Controllers (MFC), 27 high-flow, diaphragm valves, two metering valves, a static tube mixer, two Baratron absolute capacitance manometers (BACM) and two gas purifiers (See Appendix B.2).

All tube connections in the control box are made up of 316-SS micro-fit butt weld fittings, elbows, tees, and crosses.

The box is a standard sheet metal panel box and will be mounted on the northeast side of the FPD, localizing detector function close to the instrument racks. The components will be mounted on a standoff panel inside the control box, with holes in the panel door to allow access to the metering valves.

The 27 diaphragm valves control where the gas goes in the system. They will be opened and closed using pneumatically controlled solenoid valves.

The two metering valves are down stream of the detectors. One metering valve is used for the CRDCs, and the other for the IC. The metering valves will be responsible for the pressure in the detectors. A balance between the backpressure created by the metering valves, by limiting the flow out of the detector, and the MFCs controlling flow into the detector, regulates the pressure.

High purity systems have near laminar flow. Since the GHS mixes CF_4 and C_4H_{10} a method was needed to ensure proper mixing. A static tube mixer will be installed into the gas delivery system to do this. The mixer works by creating turbulent flow using a helical ribbon running through its center, forcing the gases to mix. The static tube mixer is made of 316-SS and is located directly down stream from the two CRDCs MFCs.

The two BACM and three MFCs have male VCR-4 connectors. Tube welded female VCR-4 fittings attach them to the GHS control box.

The GHS uses research purity gases, but the CF_4 and C_4H_{10} gases still possess enough impurities to adversely effect the operation of the CRDCs. Two filters are used to purify the gases, each one specific to CF_4 or C_4H_{10} . The gases are purified by using a combination of chemically reactive material and sintered stainless steel filter medium.

5.2.5 Gas Flow in the Detectors

Uniform pressure in and flow through detectors is guaranteed by having both CRDCs in series. To ensure good gas exchange, the gas enters one of the detector's window frame and leaves the other, forcing the gas to weave through the inside of the detector.

The Ion Chamber box has been designed so that the gas enters from the top and exits the bottom, also ensuring good gas exchange.

5.2.6 Roughing Pumps

The GHS has two rotary vane roughing pumps each with the capacity to pump 2.0 m³/h. Both gas detectors will operate below atmospheric pressure, and roughing pumps are used to create a vacuum forcing the gas to flow through the system.

Each pump will have an oil mist eliminator, fore line trap, and valve sentry. The oil mist eliminators limit the amount of oil that escapes into the atmosphere when the pump starts and stops (or when a load is placed on the pump). The fore line traps prevent oil from backing up and contaminating the GHS. The valve sentries are wired to the roughing pumps and in the event of a power failure, they isolate the upstream vacuum to prevent damage to the gas system. The roughing pumps and valve sentries will be located beneath the GHS control box.

To connect the roughing pumps to the control box two 1.27 cm to KF-25 butt welds are used. Vacuum hose will be used between the control box and the roughing pumps. The pumps are connected to the hose using KF-25 to KF-16 reducing flange with the KF-16 connected to the roughing pump fore line trap.

Chapter 6

The Detection System

6.1 Overview

The sweeper magnet focal plane detector has three types of detectors. Two position detectors, a multisampling ion chamber, and two plastic scintillators. The position detectors measure the two transverse positions (x and y position), the angle, and energy loss of a charged particle entering the system (Figure 6.1). One of the scintillators acts as a trigger. The other stops the particles. Collectively they provide position, angle, momentum, energy loss, total energy, timing, and particle id.

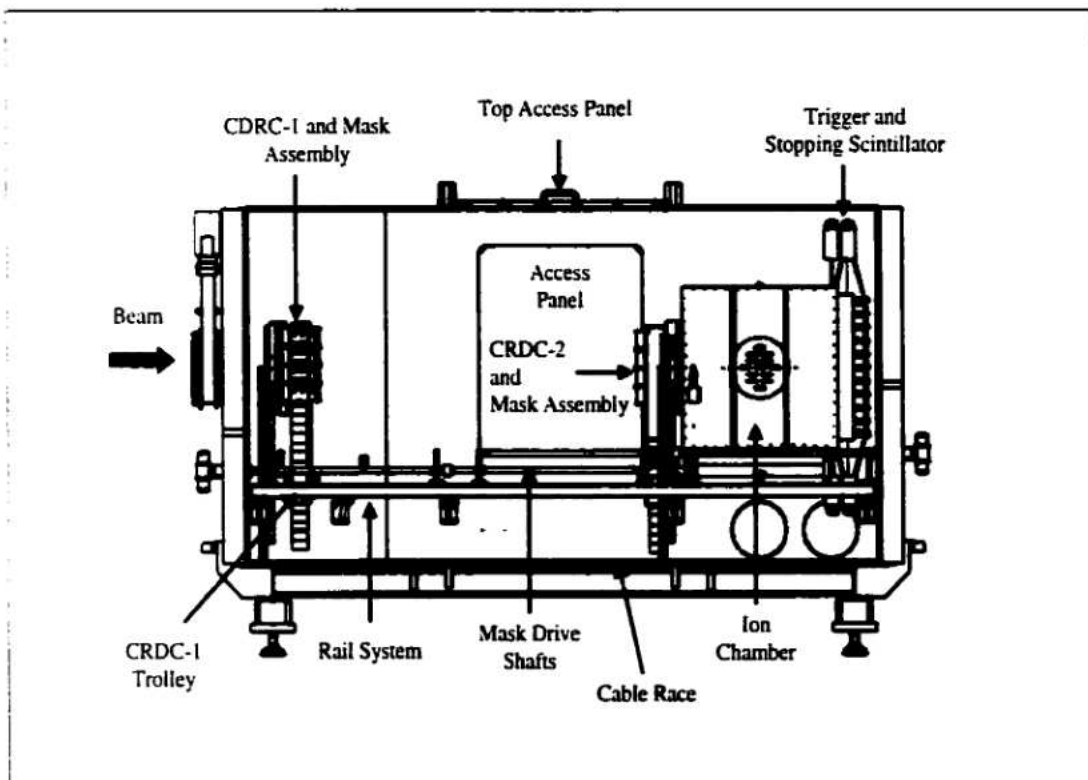


Figure 6.1: An internal view of the focal plane detector showing the layout of the detectors. The rail system allows for CRDC-1, and the CIS group to move independently allowing the detector system multiple configurations.

6.2 Geometry

The geometry of the detection system can be modified in two ways. First by changing the separation between CRDC-1 and CIS group, and by changing the distance between the two detector elements and the sweeper magnet (Figure 6.2). Second, the detector system can be collectively moved closer to the zero degree neutron flight path as discussed in section 2.2.

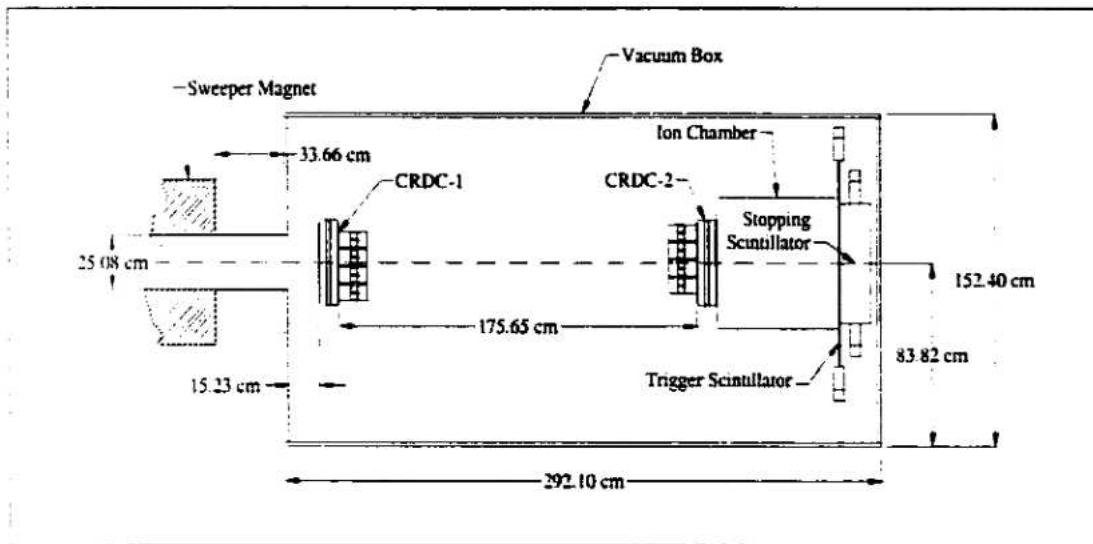


Figure 6.2: A simplified view of the interior of the Vacuum Box. Note that the CRDCs are rotated 180°.

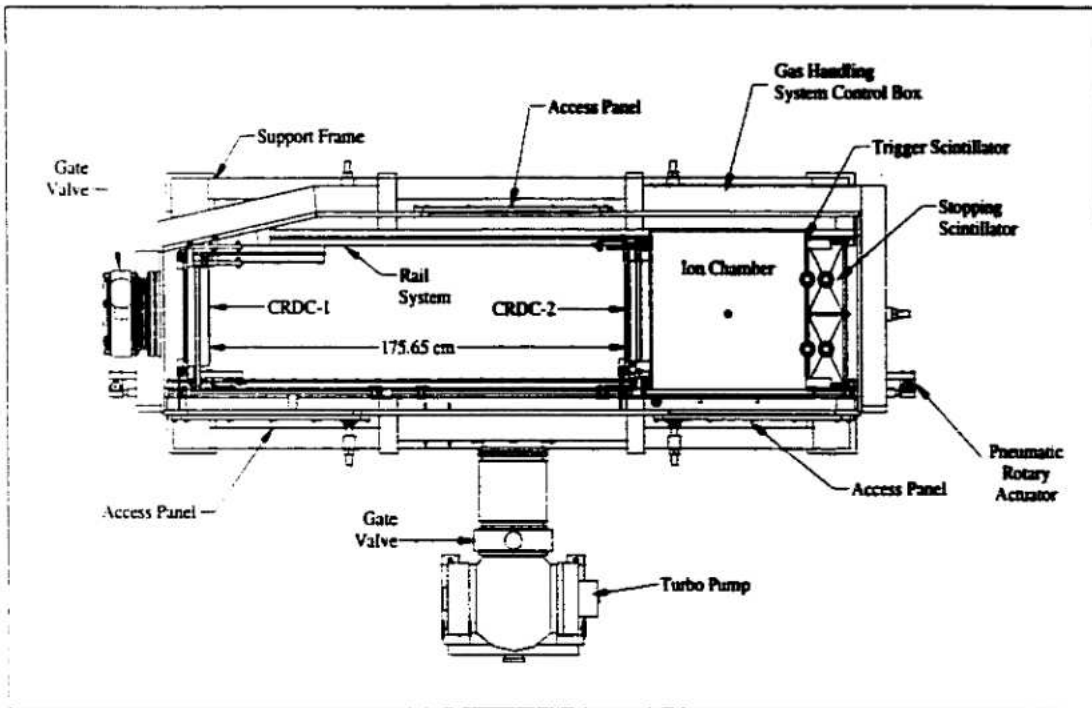


Figure 6.3: Top view of the focal plane detector showing the detector system layout.

6.3 Cathode Readout Drift Chamber

6.3.1 Overview

The focal plane detector has two CRDCs labeled in the order an ion would see them CRDC-1 then CRDC-2. The major components of the CRDCs are: two window frames and windows, two printed circuit boards, two spacers and an anode frame. Both CRDCs have an active area of 30 cm x 30 cm and an interaction length of 8.64 cm (center). The CRDC each have four front-end electronics boards (FEE) for data acquisition, and calibration masks 1.0 cm up stream from each detector for position calibration.

Table 6.1: CRDC specifications

Active Area	30 x 30 cm
Length of interaction	≈ 8.64 cm (Center)
Detector volume	≈ 7776 cm ³
Number of cathode pads per detector	232
Number of cathode pads each PCB	116
Cathode pad pitch	2.54 mm
Number of Ports	8 1/8 inch NPT
Gas used	80% CF ₄ and 20% C ₄ H ₁₀
Operating pressure	140 Torr
Rate of gas flow	≈ 35 sccm

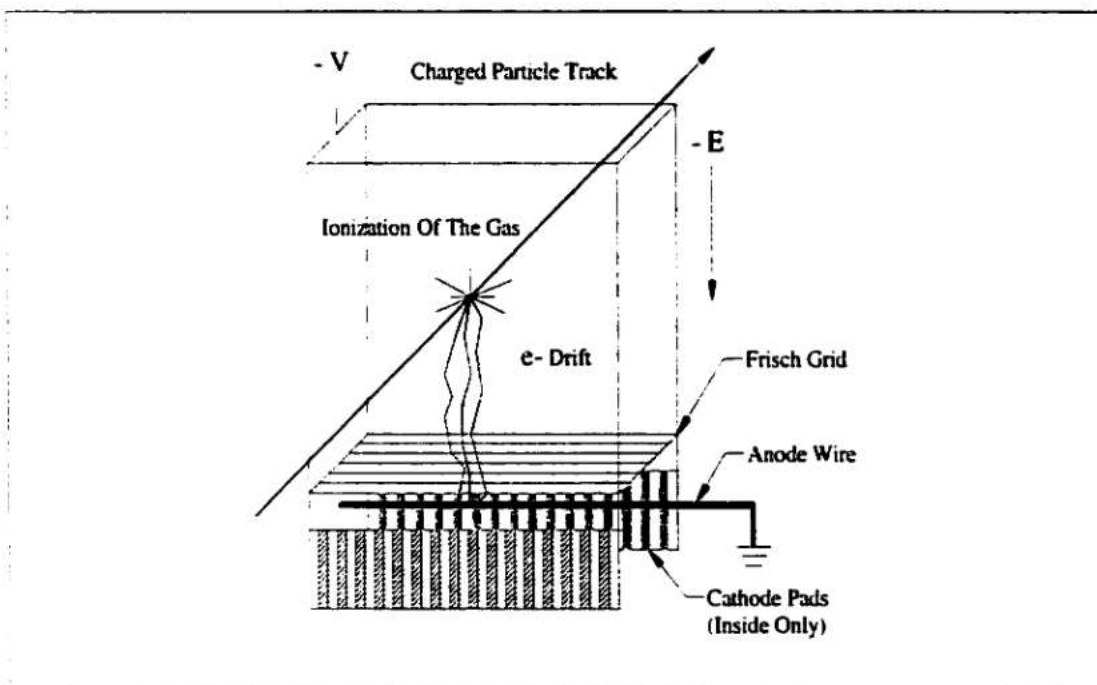


Figure 6.4: A dramatized view of the operation of a CRDC. The gas is ionized as the ion passes through the detector, and the dissociated electrons drift towards the anode wire where the charge is collected. An induced charge is created on cathode pads by this collection and provides the x position of the charged particle track. The drift time of the electrons to the anode wire provides the y position of the charge particle track. A Frisch Grid is used to remove dependence of the pulse amplitude on position of interaction with detector gas.

6.3.2 Printed Circuit Boards Assembly

The printed circuit boards are made of un-masked G-10. The boards have laminated to them on both sides, two 0.508 mm G-10 “spacers”. The spacers ensure a proper “O” ring seal between the PCBs, window frames, and anode frame. An additional piece of G-10 is laminated to the PCB covering the high voltage trace to prevent sparking (Figure 6.5).

Each PCB will have a field shaping foil stretched over its aperture. The foils are made of stretched polypropylene, $100 \mu\text{g}/\text{cm}^2$ thick, with 1.9 mm pitch evaporated aluminum strips on the surface, the strips running perpendicular to the electric field. The field shaping foils ensure a uniform electric field in the active region of the CRDC.

All the electrical components necessary are then attached to the PCB (Except the thirty-four pin connectors used for the FEEs).

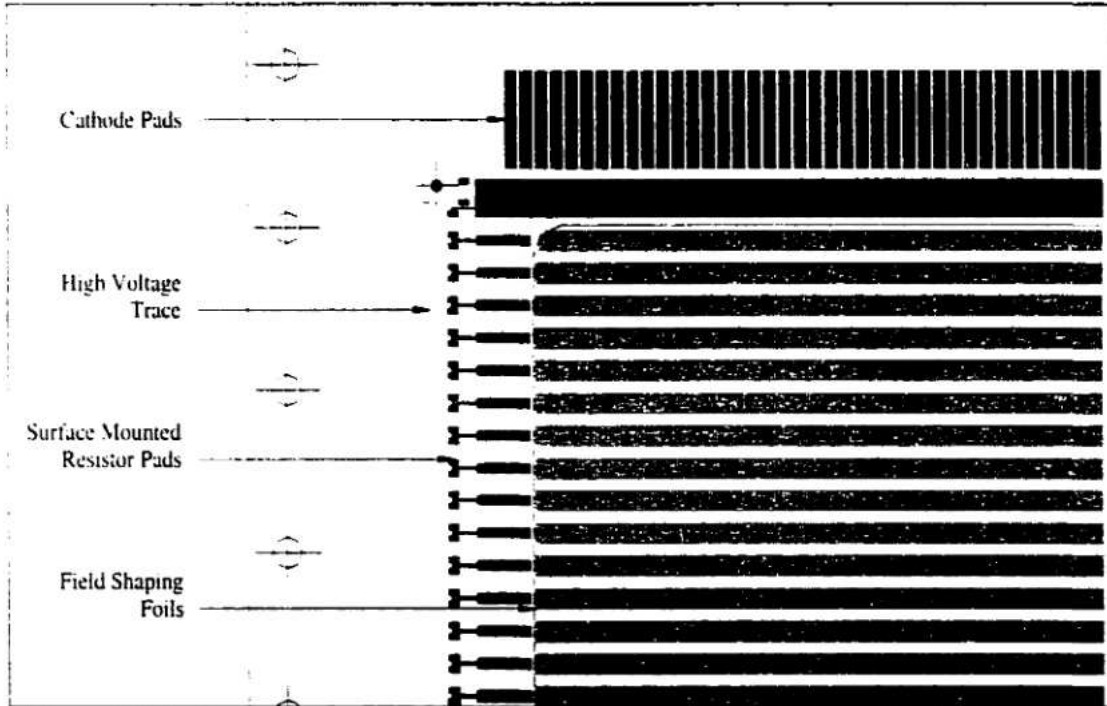


Figure 6.5: A close up view of a PCB shows the high voltage trace that will be covered with a strip of G-10 to prevent sparking. To the left is the field shaping strips, and on top the cathode pads.

6.3.3 Window Assembly

The window frames are constructed of aluminum and have: sixty through holes, an "O" ring groove around the edge, and four ports on opposite sides (Figure 6.5a). To contain the gas within the detector, the CRDC windows have 50 microns of PPTA, poly(p-phenylene terephthalamide) glued to the window frame along the curved gluing surface (Figure 6.6). This curvature increase the pressure the PPTA can withstand. The window frames should always have this curvature "bowed" outward, from high to low pressure. PPTA windows will be glued to both window frames of CRDC-1, and one of CRDC-2 window frames. The second window frame of CRDC-2 is the window for both CRDC-2 and the ion chamber. The pressure gradient between CRDC-2 and the ion Chamber is greater than between the CRDCs and the vacuum box. To provide additional strength this window is made with Kevlar instead of PPTA.

Unlike the other three window frames, this one is reversible and it has "O" ring grooves on both sides to accommodate different pressure configurations

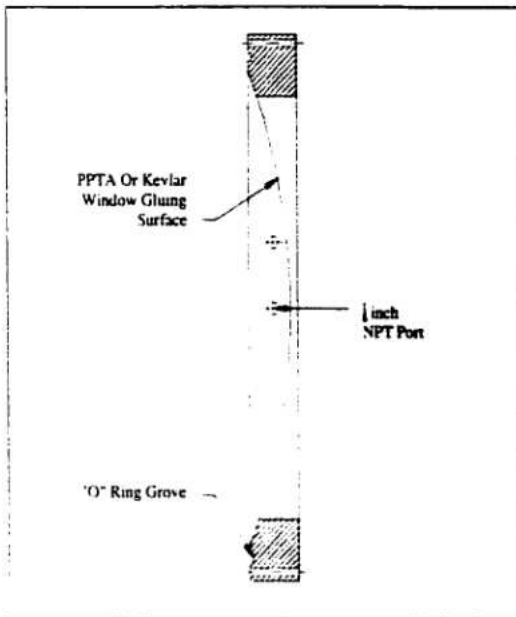


Figure 6.6: Cross-section of the CRDC Window Frame. Each frame has four ports that can be configured for a pressure, temperature, transducer or gas in/out depending on which CRDC.

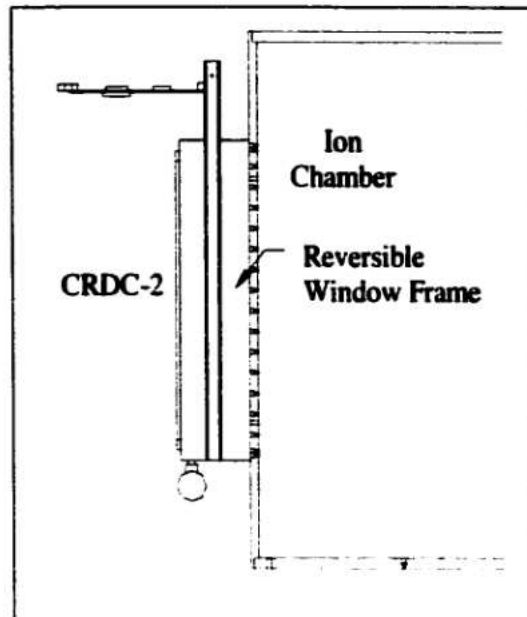


Figure 6.7: One window frame differs from the others by being reversible by having "O" ring grooves on both sides. This view shows the location of the reversible window frame.

6.3.4 Anode Frame Assembly

The anode frame is made of the same G-10 as the PCBs, but is 1.52 cm thick. The frame has: sixty 10-32 through holes, an "O" ring groove around both sides of the larger aperture, and 4 threaded 10-32 hole around the smaller one. Assembly begins with the installation of the cathode grounding plane along the bar separating the small and large aperture (Figure 6.7). Made of 0.3175 cm copper coated G-10, the grounding plane is 33.3 cm long and 1.52 cm wide; it is glued to the anode frame just below the small aperture. A wire is fed through the left and right sides of the frame making an electrical connection.

Next, two copper tubes, 40 mils OD and 20 mils ID are glued into the frame from both sides (Figure 6.8). The anode wire is installed through the tubes and glued into place with conducting epoxy (Figure 6.8).

The Frisch grid is made by gluing both 0.635 cm x 0.635 cm x 1.5 cm copper bars to the two G-10 wire insulators. Both wire insulators have two 4-40 holes and are attached to a 33 cm x 3 cm aluminum bar. Then 12-micron gold plated tungsten wire is glued with conducting epoxy to the two copper blocks, forming a violin bow like structure. When the epoxy is dry the four screws are removed from the aluminum bar and the wire bar, insulator, and Frisch grid are installed into the anode frame with four 316-SS 4-40 screws, stretching the grid tight. A wire is connected to the copper block to make the electrical connection.

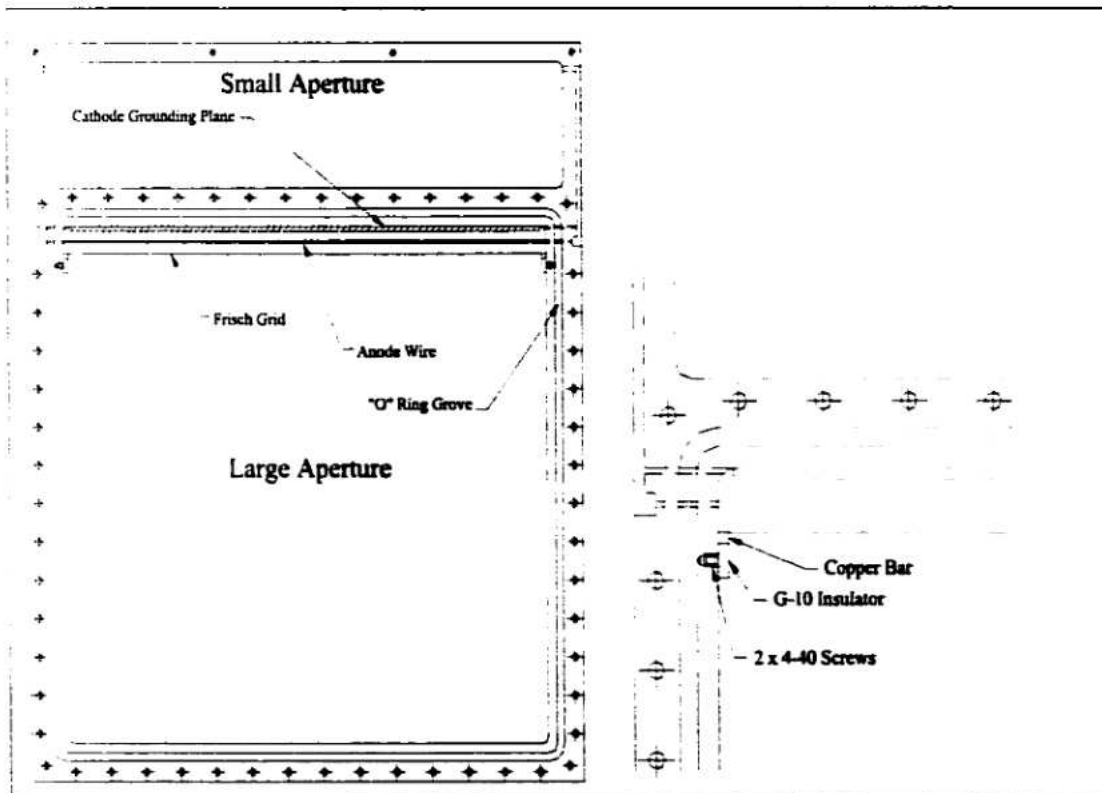


Figure 6.8: The left figure shows the location of the anode wire, Frisch grid and cathode grounding plane. The figure on the right shows the location of the copper bar and wire insulator.

6.3.5 Assembly

Four 0.3175 cm Viton “O” rings are placed into the two windows and anode frame “O” ring grooves. The anode frame is then sandwiched between two PCBs with the cathode pads facing each other. The four 34-pin ribbon cable connectors are installed electrically connecting the two PCBs together. The anode frame and PCBs are then placed between the two window frames (Figure 6.7). Sixty 10-32 x 10.16 cm 304-SS bolts with the 10-32 304-SS nuts and washers are used to hold CRDC-1 together. For CRDC-2, the stainless steel bolts are mounted to the side of the Ion Chamber box.

Two of the ports in the window frames are used for detector gas delivery, with two custom VRC-8 males to 0.3157 cm NTP connectors being used. The BACM is installed into one of the ports with a male VCR-4 elbow to a 0.3175 cm NTP connector. Another port will be used by the temperature transducer, which uses a bored 0.3175 cm NPT plug. The remaining 4 ports will have 0.3175 cm NPT plugs installed. All are made of 316-SS, with Teflon tape to seal the threads. The CRDCs are installed into the FPD, with one rotated 180° relative to the other.

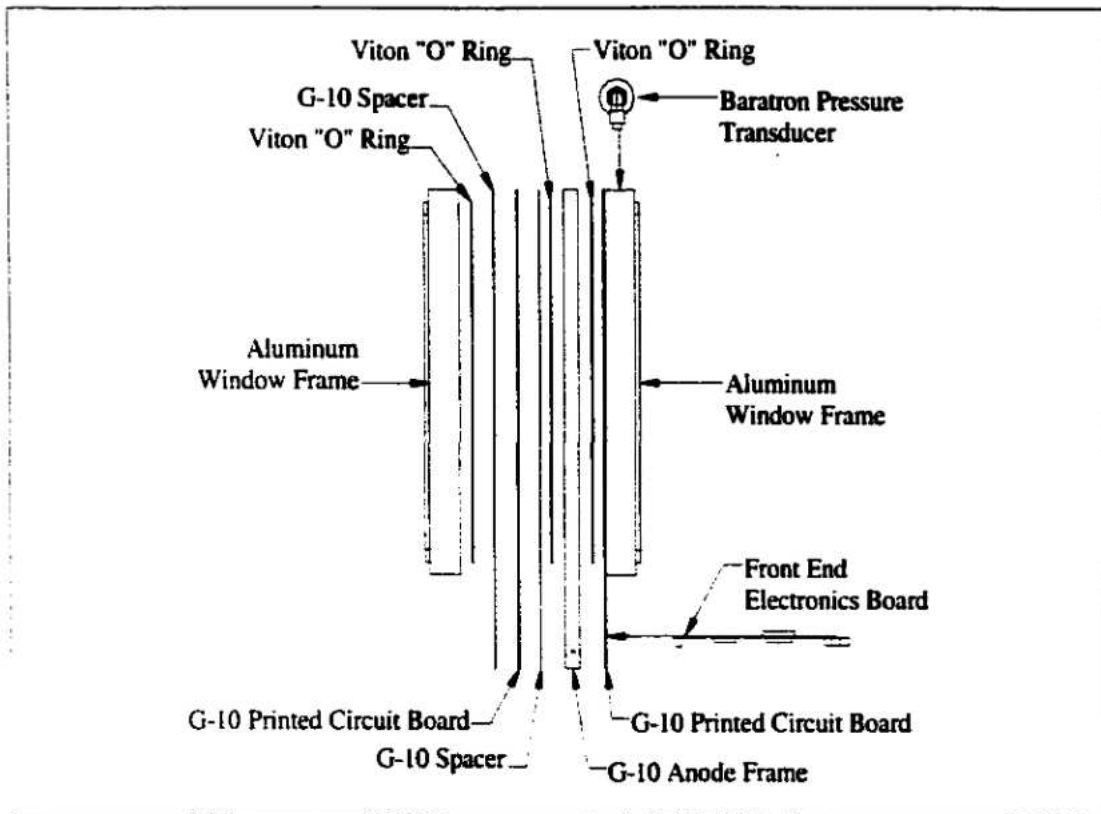


Figure 6.9: Exploded view of a CRDC. The G-10 spacers are laminated to the printed circuit boards with TRA-Bond F-113 epoxy. This provides a good "O" ring seal between the PCB, window frame, and anode frame. The electrical connection is made between both PCBs with the 34-pin ribbon cable connectors.

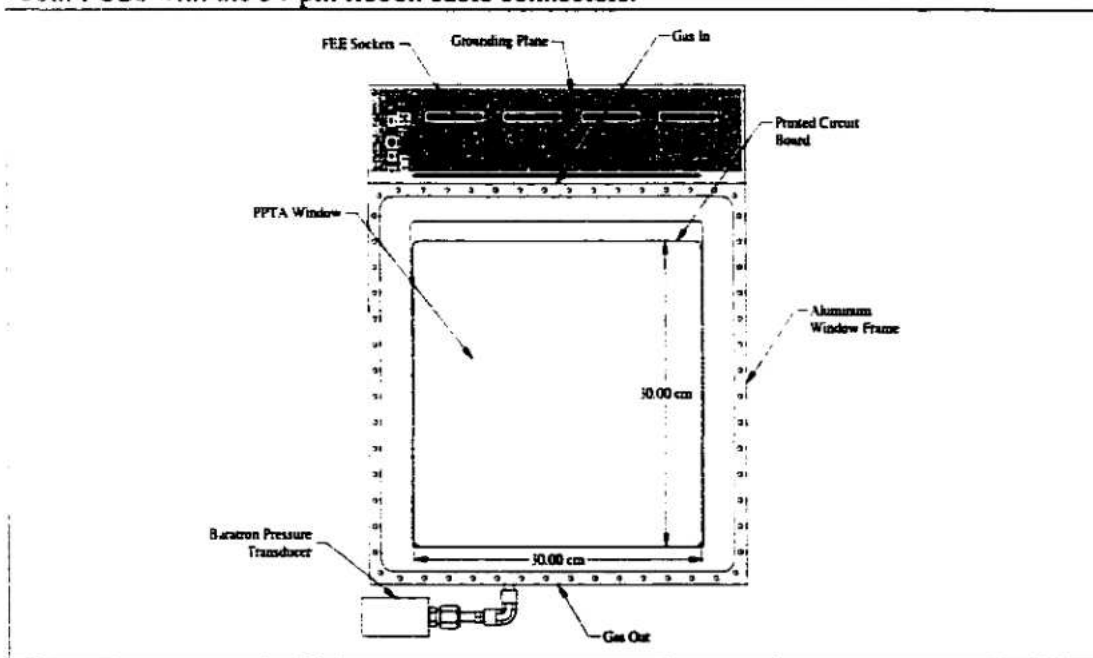


Figure 6.10: An end-on view of the CRDC assembly.

6.4 The Frisch Gridded Ion Chamber

6.4.1 Overview

The focal plane detector has a multi sampling Frisch Gridded ion chamber. The Chamber is located between CRDC-2 and the two scintillators, with CRDC-2 and the scintillators forming the Ion Chamber's windows.

Table 6.2: Ion chamber specifications

Active Area	40 x 40 cm
Length of interaction	≈ 53.09 cm
Detector volume	≈ .277 m ³
Number of anode pads	16
Anode pad width	3.08 cm
Gas used	P-10 (80% Ar and 20% CH ₄)
Operating pressure	300 Torr
Rate of gas flow	≈ 35 sccm

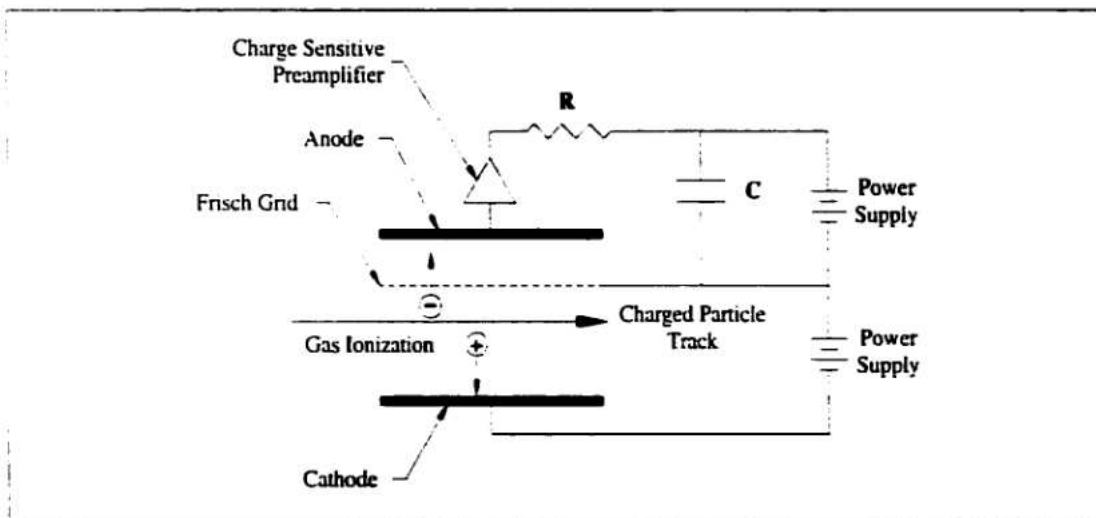


Figure 6.11: This figure shows the operation of a single pad in the ion chamber. The electrons are collected on the upper plate creating an increase in voltage across the resistor. This is what we see as a signal. The Frisch grid removes amplitude dependence position.

6.4.2 The Ion Chamber Box

The Ion Chamber box is made of 1.27 cm 304-SS and weighs 233 kg. The interior is electro-polished and has a volume of .27 cm³. There are two 0.3175 cm “O” ring grooves in the box where CRDC-2 and the trigger scintillator form the windows.

The box’s door can be accessed from both of the FPD south access panels, and is sealed with 0.3175 cm Viton “O” ring and eighty 10-32 SS bolts.

Mounted in the door is the same thirteen 34-pin ribbon cable feedthrough as the vacuum box. On the door will be: a VCR-4 male connector for the pressure transducer, a 0.3175 cm NTP tap for the temperature transducer plug and two Reynolds connectors for the two high voltage power supplies connection.

The detector gas will enter through two male VCR-8 connectors located on top and bottom of the box.

6.4.3 The Ion Chamber

Inside the ion chamber box is the ion chamber. The chamber consists of: a cathode plate, two entrance boards, two exit boards, a Frisch grid, an anode board, 4 supports, 4 spacers, 4 mounting feet, and a mounting plate.

6.4.4 Ion Chamber Assembly

The ion chamber is assembled as depicted in Figure 6.12. The cathode will be made of 304-SS 1.524 cm thick. The rest of the boards will be made of 0.3175 cm thick cryogenic G-10 (used for it’s low out-gassing properties), except the anode board, which is 0.15 cm thick.

The two field boards run parallel to the beam axis. The two entrance windows have apertures with field-shaping foils stretched over them. The foils are made of

stretched polypropylene, $100 \mu\text{g}/\text{cm}^2$ thick, with 0.254 cm pitch evaporated aluminum strips. Coated with copper, both are used as electric field shapers, and both boards have etched 0.245 cm pitch strips running perpendicular to the field.

The Frisch grid creates the bottom of the ion chamber. It is made of 0.635 cm thick aluminum, with 12 micron gold plated wire stretched across, perpendicular to the beam axis.

The upper portion of the ion chamber is supported by four 31.24 cm 1.90 cm x 1.90 cm Delrin bars (Delrin is used because of its hydrophobic properties). The bars have six 8-32 threaded holes, and Delrin screws are used to secure supports to the boards. Aluminum attach clips are mounted to the support bars and Frisch grid to provide additional strength. Delrin spacers of 1.90 cm x 1.90 cm x 2.16 cm are used to separate the Frisch grid and the anode board below it.

The anode board will have an additional piece of 0.15 cm cryogenic G-10 laminated to the back to flatten the board out and provide extra strength. The board is segmented into sixteen 2.54 cm pads perpendicular to the beam axis, and will have 16 Cremet 101D charge sensitive amplifiers installed along one side.

Supporting the whole structure are four Delrin feet (tees). They will be mounted on a 0.3175 cm stainless steel plate so that the chamber can be slid in and out easily.

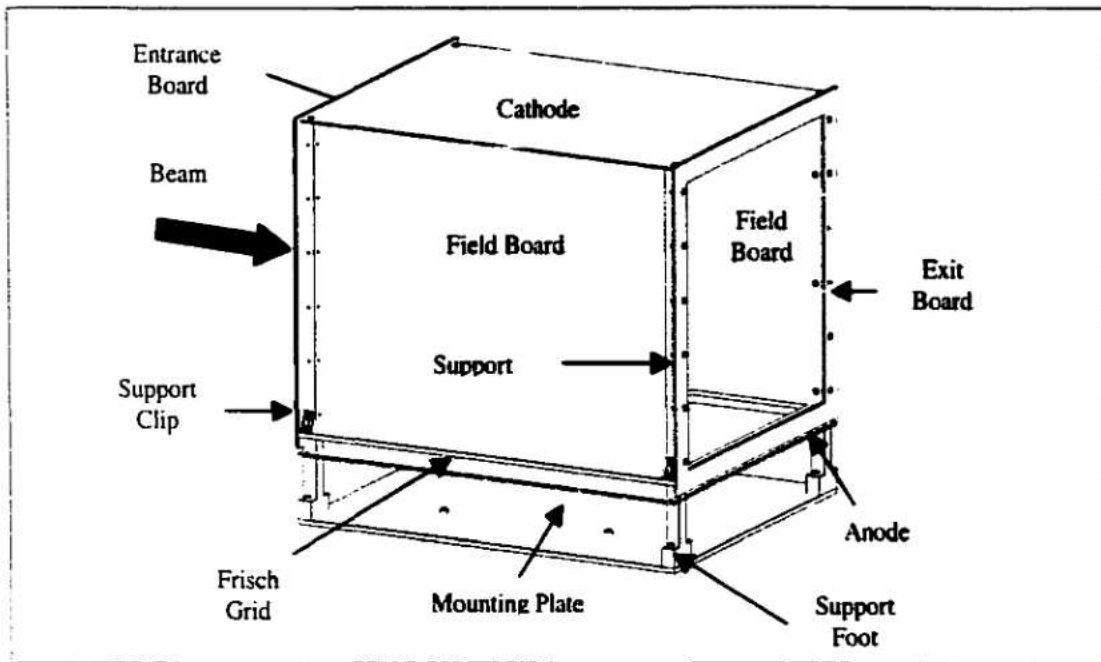


Figure 6.12 A three dimensional view of the ion chamber's components and assembly.

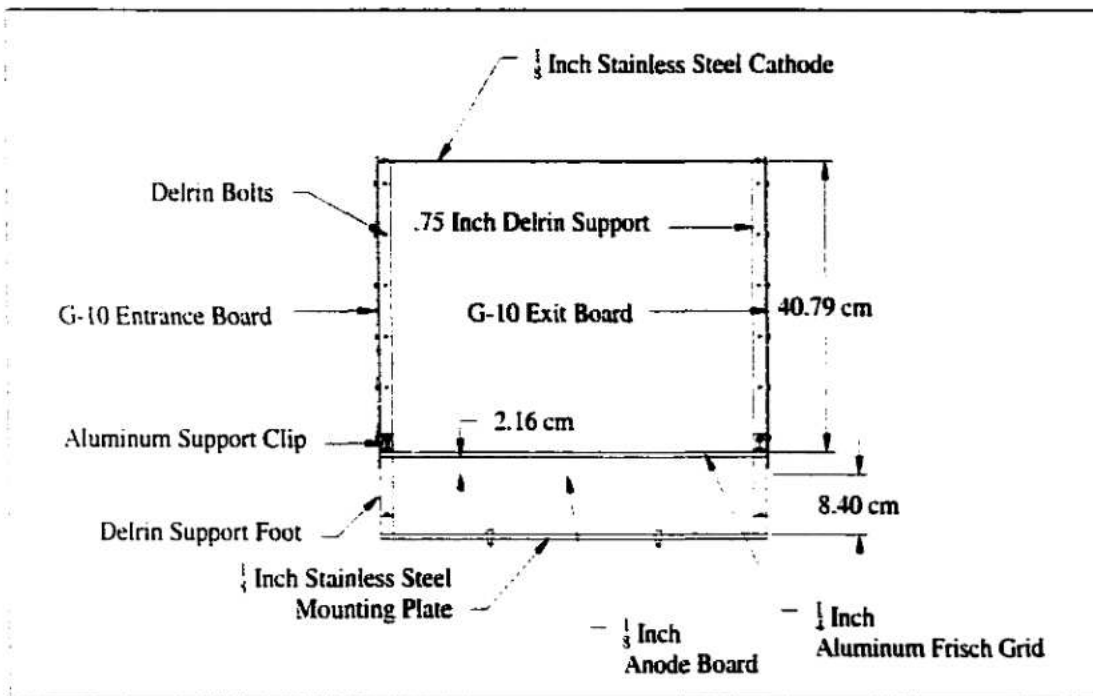


Figure 6.13: Side view of the Ion Chambers assembly.

6.5 Organic Scintillators

6.5.1 Overview

The Focal Plane Detector will have two organic scintillators made of Pilot-B (BC-404) labeled trigger and stopping. The emission of Pilot-B has a maximum output around 425 nm (violet to ultra-violet). This material was selected for its fast 1.8 ns time constant and high light output.

Located after the ion chamber, the scintillators will be against each other, forming a window of the ion chamber box. Both scintillators have an active area of 55 x 55 cm. The trigger scintillator is 0.5 cm thick, while the stopping scintillator is 15 cm thick. Each scintillator will use four photo multiplier tubes (PMT) but only the trigger scintillator will have lightguides.

Table 6.3: Scintillator specifications

Active Area	50 x 50 cm
Thickness of the Trigger Scintillator	0.5 cm
Thickness of the Stopping Scintillator	15.0 cm
Composition	Pilot-B (BC404)
Maximum emission wavelength	425 nm (violet to ultra-violet)
Time constant	1.8 ns

Table 6.4: PMT Specifications

Type	Hamamatsu R329-02
Spectral response range	300 to 650 nm
Dynode Structure/# of stages	Line/12
Anode to cathode supply voltage	2500 V DC
Gain	1.1×10^6
Dark current	6 nA
Window	Borosilicate glass
Window diameter	51 mm

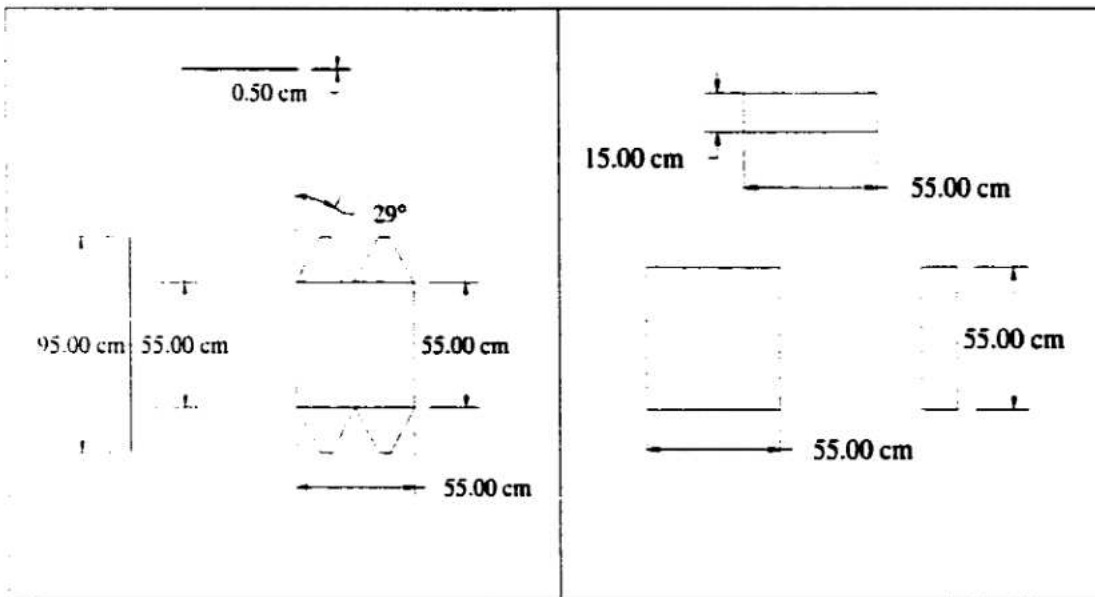


Figure 6.14: Trigger scintillator dimensions. Note the "fish tail" lightguides.

Figure 6.13: Stopping scintillator dimensions.

6.5.2 Photo Multiplier Tubes

Each scintillator will use **4 Hamamatsu R329 PMTs** fitted with magnetic shielding.

6.5.3 Assembly

The PMTs will be mounted directly to the scintillators with **TRA-Bond F-113** epoxy. Four “fish tail” lightguides will be attached to the trigger scintillator in the same way. Both scintillators will be wrapped in aluminum foil, excluding the trigger-stopping scintillator interface and **Ion Chamber box trigger scintillator interface**. A support and mounting bracket will be used to hold the scintillators together and to the ion chamber box. Because the lightguides for the trigger scintillator are so thin, a support will be used to hold the trigger scintillator **PMTs**.

Chapter 7

The Data Acquisition System

7.1 Overview

The focal plane detector data acquisition system will be made up of the equipment and software needed to collect and process the data acquired by the three detectors.

7.2 Operation

The computer will be a dual processor IBM/PC (rack mounted) running a Linux operating system. Connected to the VME crate, the data acquisition computer will have a program called "Readout" installed in it. This program handles the communication, collection, monitoring, and exporting of all data collected by the three detectors. Readout exports the data using the Ether Net (TCP/IP) to the Spectrodaq data server. From there the data stream separates into two dataways. One dataway goes to a stager where data is saved to disk or to 8 mm tape. The other dataway goes to any computer on the network with the Focal Plane Detector specific SpecTcl (Cosy-Infinity) program installed. SpecTcl is a powerful nuclear event data analysis tool and Cosy-Infinity is an arbitrary order beam physics code used for inverse mapping of particle trajectories. These programs provide an object oriented C++ framework for histogramming and other data analysis operations. From here the data is exported to a stager and stored on disk, 8 mm. tape, or displayed for the user (Figure 7.1).

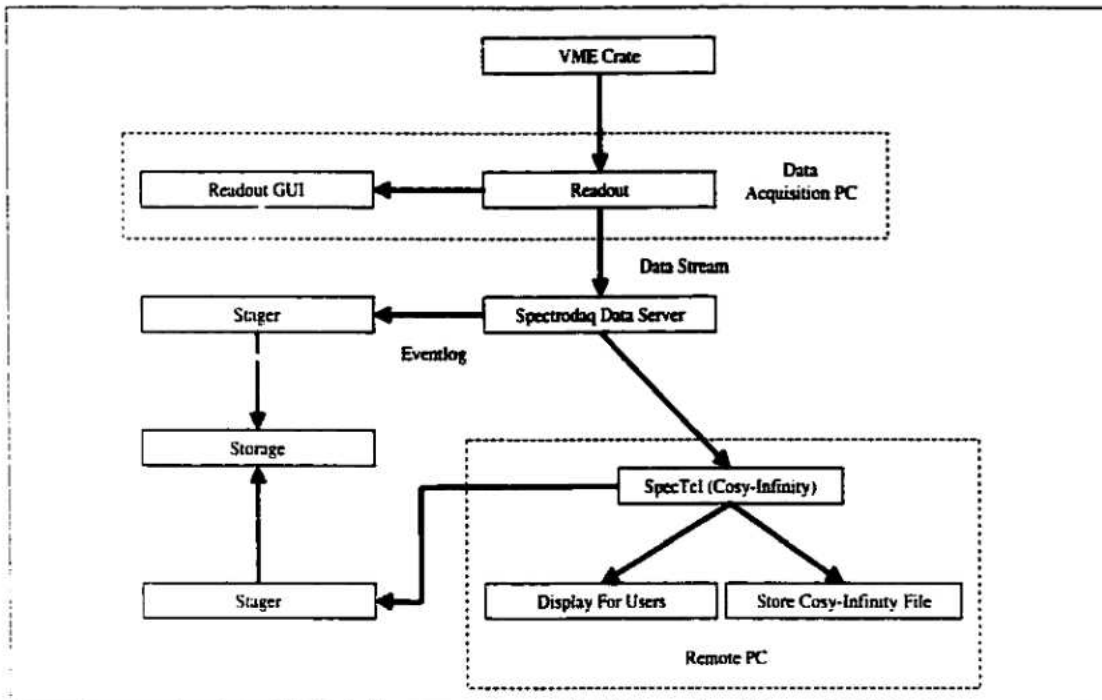


Figure 7.1: Data acquisition layout. All network communication will be done with TCP/IP.

7.3 CRDC Data Acquisition

Each CRDC data acquisition system will consist of two dataways, one for the cathode signal and one for the anode signal. When charge is collected a signal is sent to the FEE where it is amplified with a charge sensitive pre-amplifier, shaped, and then digitized using an ADC. The signal is converted from TTL to ECL in a converter box. Then it is sent to the Jan Toke x-module, and from there it is exported to the data acquisition computer via the VME crate.

The anode signal (from the anode wire) is amplified using a charge sensitive pre-amplifier, and then sent it to a TFA to be filtered. The signal goes to a CFD to provide a logic pulse. This pulse bifurcates to a scalar, which counts the number of pulses, and to a TDC, which convert the pulse to a time. Both signals enter the data acquisition computer via the VME crate.

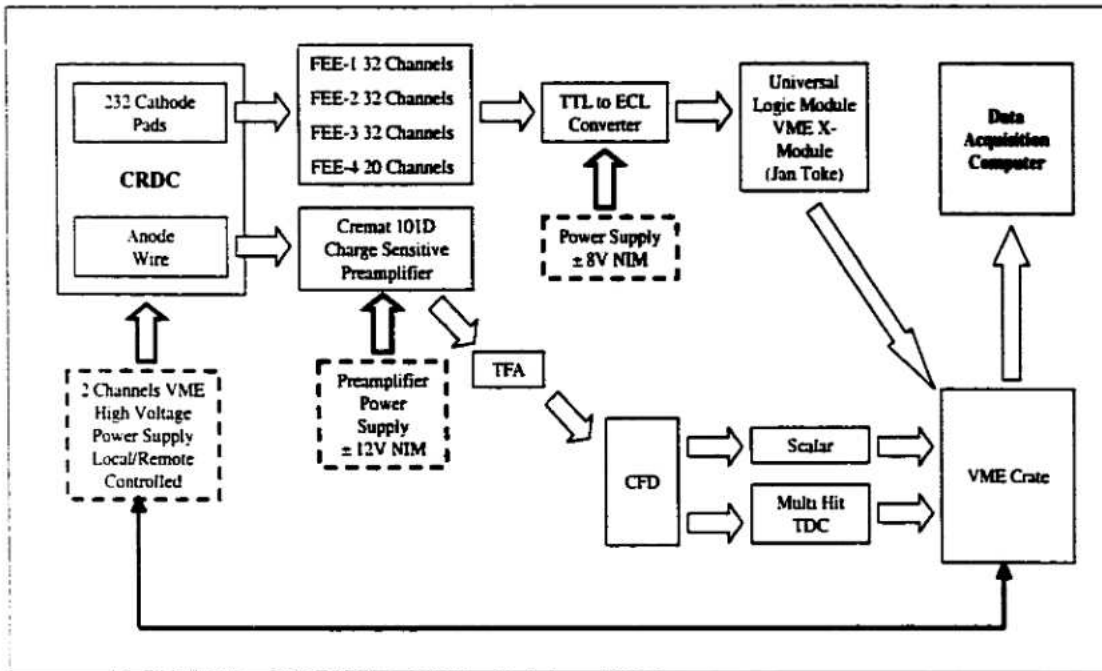


Figure 7.2: Schematic of the CRDC data acquisition electronics. Only one of the CRDC's is represented here.

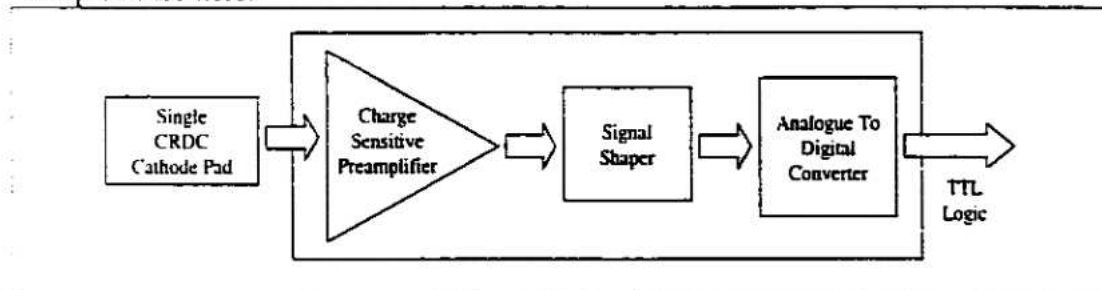


Figure 7.3: This describes the operation of the CRDC Front End Electronics (FEE) for a single cathode pad. Each CRDC has three boards with 32 channels and one with 20. There are a total of 116 channels per CRDC.

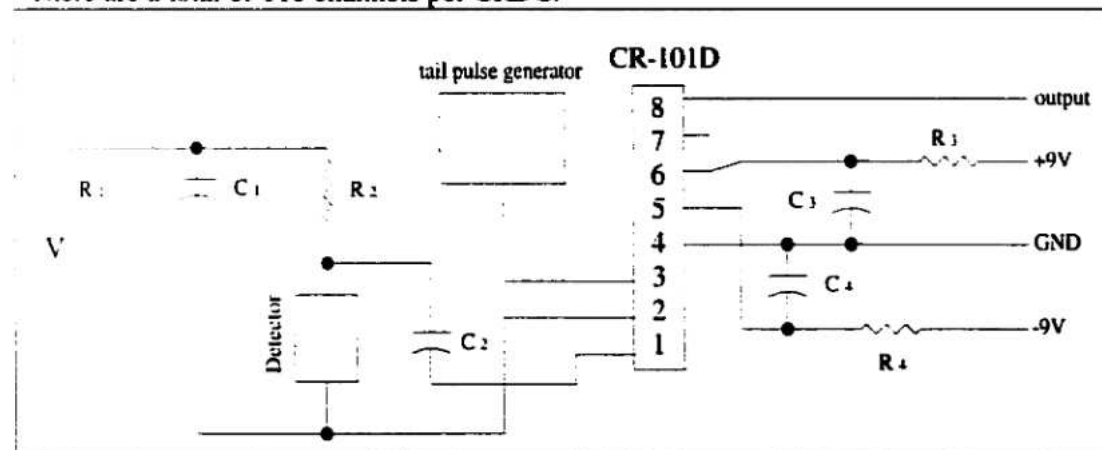


Figure 7.4: CRDC anode wire preamplifier circuit. Each CRDC has one located as close as possible to the anode wire to minimize noise. $R_1=10M\Omega$, $R_2=100M\Omega$, R_3 and $R_4=100\Omega$. C_1 and $C_2=0.01\mu F$, C_3 and $C_4=10\mu F$.

7.4 Ion Chamber Data Acquisition Electronics

When charge is collected in the ion chamber, the 16 charge sensitive pre-amplifiers send an amplified voltage pulse to the signal shaper where the signal is processed. Next the signal is converted from an analogue signal to a digital one. These signals are then exported to the data acquisition computer via the VME crate (Figure 7.3).

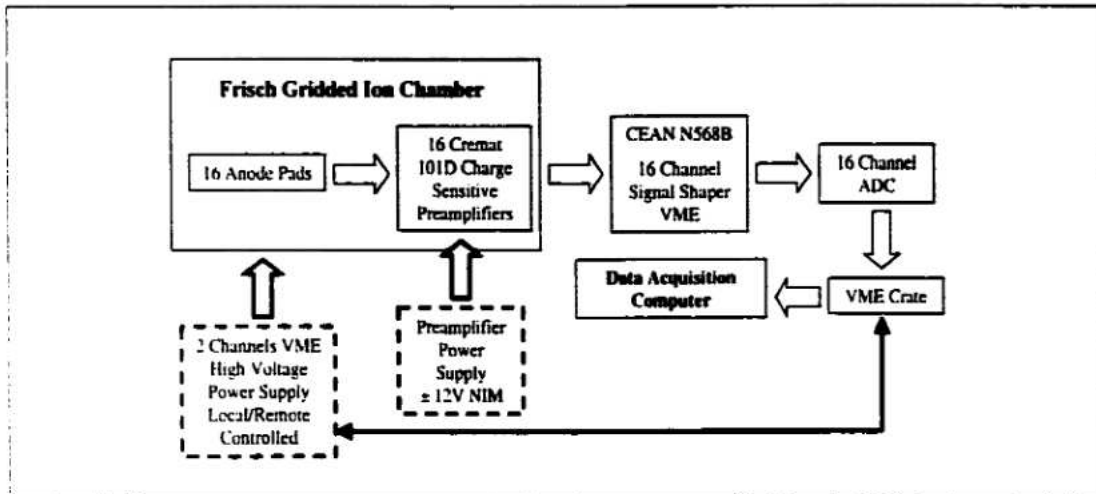


Figure 7.5: Schematic of the ion chamber data acquisition electronics.

7.5 Scintillator Data Acquisition

Each scintillator will have four Hamamatsu R329 PMTs using Iseg integrated HV supply PMT Bases. Communication with the bases will be done using VME Iseg CI08 remote control CAN-Interface modules each of which has two channels (A total of four modules will need to be purchased). The signals are then sent to the data acquisition computer via the VME crate.

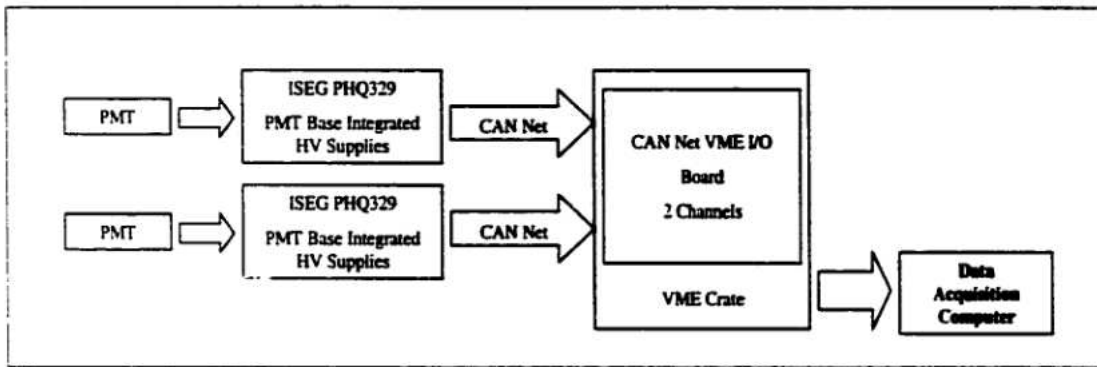


Figure 7.6: Schematic of the data acquisition electronics for both the trigger scintillator and the stopping scintillator. This figure only represents two photo multiplier tubes. Each scintillator has four PMTs.

7.6 Instrument Crates

Three instrument crates will be used by the FPD, NIM, CAMAC, and VME. The crates will be located in the N-4 FPD relay rack. The NIM crate uses an external dataway to export signals. These signals can go either to the CAMAC or VME crate depending on the detectors electronics configuration. The CAMAC crate exports signals to the VME crate where a VME parallel port interface is used to connect the VME crate to the data acquisition PC.

7.7 Low Voltage Power Supplies

An optically isolated NIM module will be designed and built to supply five channels of “clean” low voltage power. This module will be used to provide the charge sensitive pre amplifiers with $\pm 9V$, the TTL to ECL converter box with $\pm 8V$ and temperature transducers with $\pm 12V$.

7.8 Definitions

Instrument	Description
NIM (Nuclear Instrument Module)	Instrument "crate" limited data way and logic bus
CAMAC (Computer Automated Measurement and Control)	Instrument "crate" based data way and logic bus
VME	Instrument "crate" based data way 32-Bit and logic bus
CFD (Constant fraction discriminator)	The module accepts negative inputs and produce differential ECL outputs that are available both in a prompt and a delayed output. The Timing Stage of the discriminator produces an output pulse whose width is adjustable
TAC (Time to amplitude converter)	Each time interval between a Common Start and the individual channel inputs or between the individual channel inputs and a Common Stop is converted to a voltage level.
ADC (Analogue to digital converter)	Converts an analogue signal to a digital pulse
FERA (ADC Fast encoding reading analogue to digital converter)	Converts an analogue signal to a digital pulse (Charge integrators)
Scalar	Collects and counts the number of logic pulses over an interval of time.
Multi Hit TDC (Time to digital converter)	Built around a multi-channel TAC (Time to Amplitude Converter) the time interval between a common start and stop is converted a voltage level then to an ADC (Analogue to digital converter)
TTL (Transistor to transistor logic)	Digital logic
ECL (Emitter coupled logic)	High speed digital logic
TFA (Timing filter amplifier)	Filters analogue signal noise from preamplifiers while preserving timing information.
Signal Shaper	A spectroscopy amplifier it accepts the typical inputs generated from nuclear particle detectors and output signal pulses that can be varied in gain rise time and decay time.

Chapter 8

The Control System

8.1 Overview

Control and monitoring of the Focal Plane Detector will be done using the, Modicon-PLC control system, a VME/EPICS instrument crate, and a local IBM/PC. The systems that will be controlled are, Gas, Vacuum, Cooling, and Mechanical Systems. The layout and functions of the Control System can be seen in Figure 8.1. The PC (Control PC) will be running on a Windows NT platform and located next to the FPD relay rack.

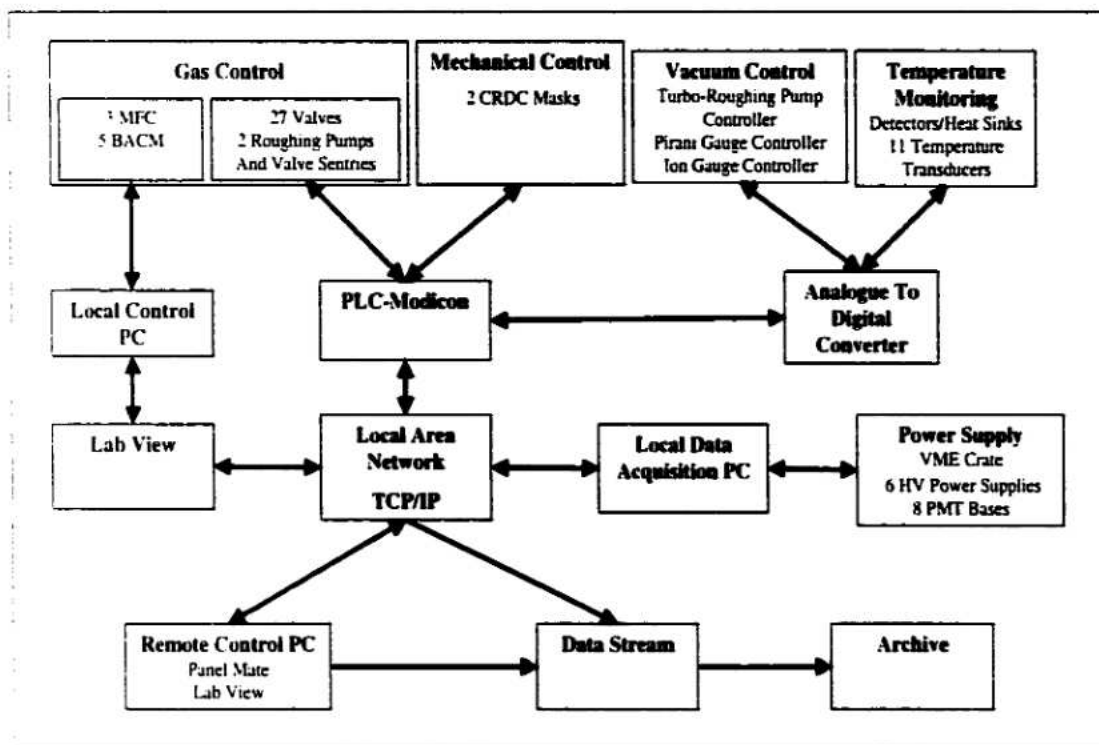


Figure 8.1: A layout of the control and monitoring system. Detector status information necessary can be archived.

8.2 Modicon-PLC

Modicon- Programmable Logic Controller (PLC) is a special purpose computer designed for remote monitoring and controlling of processes using input/output modules. It uses a specialized machine control language called ladder logic. The detector will have systems that use both analogue and digital signals for control and monitoring. Digital signals can go directly into the Modicon-PLC coils. The analogue signals need to be converted to a digital signal using an analogue to digital converter (ADC) then enter the Modicon-PLC.

8.3 Software

The software needed to operate the FPD is currently in development. Three types of software will be used to ensure a robust system, Panel Mate, Lab View and the Modicon-PLC ladder logic. Panel Mate and Lab View both use a graphical user interface (GUI) to display information; the ladder logic sits in the background.

A control panel has been written using Panel Mate as a proof of principle. It is organized around the four basic Focal Plane Detector control processes. These processes are: the gas systems (vacuum and gas handling), temperature monitoring, motion control and the high voltage power supplies.

Lab View differs from Panel Mate in the level of sophistication of its GUI, and provides a more intuitive picture of the system functions. Using Lab View will provide an additional layer of safety to prevent accidents by visual or audible means. Eventually four Lab View virtual instrument panels (VI) will be developed and broken into the previously discussed four process control areas (this is to ensure uniformity between Lab View and Panel Mate).

The most robust portion of the control software is the Modicon-PLC ladder logic. All the logic necessary for control and monitoring of critical systems will be located here. The advantage is, in the event of a software “crash” or hardware failure, the critical system can either go into a standby mode or continue to operate at the previously set value until communication can be reestablished.

The software will be designed to allow control and monitoring of the detector systems next to the FPD. Or control and monitoring could be done remotely with any computer on the network with appropriate control software (Panel Mate and or Lab View) installed.

8.4 Vacuum System Control And Monitoring

The vacuum system has five components that will be controlled and monitored. These include: an ion gauge controller, CEP gauge controller, the turbo-roughing pump controller, and the two gate valves. The pressure in the vacuum box is monitored using a convection enhanced Pirani gauge (CEP) for pressures of 760 Torr to 1.0×10^{-3} Torr, and an Ionization gauge for pressures of 1.0×10^{-3} to 2.0×10^{-11} Torr. The controllers communicate using an analogue output voltage sent into an ADC then into the Modicon-PLC. The ion gauge controller has three channels: turning the ion gauge on/off, degassing the gauge, and pressure measurement. The CEP gauge controller has only one output channel for pressure measurement. The turbo-roughing pump control has four channels for turbo pump on/off, roughing pump on/off, turbine speed, and a pressure read back. (this is to ensure that the turbo pump is not at the proper vacuum when it is turned on). The two gate valves are controlled directly through the Modicon-PLC since they operate logically (open/close).

8.5 Mass Flow Controllers and Baratron Pressure Transducers

Control and monitoring of the gas handling system will be done using a MKS 186B process controller. The 186 controller performs closed-loop process control of the three Mass Flow Controllers, (MFC), and the five BACMs making up the gas handling system. The 186B instrument is connected to the control computer via an RS 232 interface using either the parallel or serial port.

The purpose of the MFCs is to control the flow of gas into the detectors and the mixing of the two CRDC gases. During operation they will operate approximately between 25 to 35 sccm, but MFCs do have a maximum capacity up to 500-sccm full scale (to allow for rapid filling).

The Baratron absolute capacitance manometer (BACM) monitors the pressure in the detectors as well as the pressure post MFC (see Appendix B). The BACMs provide feedback so that the MFCs can adjust the flow rate based on this pressure input.

The 186 controller uses a Proportional-Integral-Derivative (PID) control algorithm to adjust the output of the Mass Flow Controller based on the pressure input signal. The 186 instrument reads the pressure input signal, compares the reading to the user-defined set point, and calculates the output signal necessary to position the MFC(s) to achieve or maintain the desired set point pressure or mixture of gases. Lab View VI panels have been provided by the manufacturer to communicate with the 186B instrument.

Table 8.1: MFCs' and BACMs' specifications

Instrument	Capabilities
Mass Flow Controller	<p>Max rate of flow is 500scm Error is $\pm 1\%$ Max inlet pressure 7757 Torr Max pressure differential 517 to 2068 Torr Warm up time 2 min Fitting VCR-4</p>
Baratron Absolute Capacitance Manometer	<p>Max pressure is 5000 Torr Error is $\pm 1\%$ of reading Fitting VCR-4</p>

8.6 Solenoid Controlled Pneumatically Operated Diaphragm Valves

There are a total of 27 diaphragm valves in the GHS. Each of the valves has a pneumatically controlled solenoid through the Modicon-PLC $\pm 24V$ coils. The control box will have a phone relay block in it to make the electrical connections to each solenoid (see appendix B.1) and will be connected to the air inlet in series.

8.7 Roughing Pumps and Valve Sentries

There are two roughing pumps with vacuum sentries in the GHS. The valve sentries and pumps will be connected to the same power source. In the event of a power failure the gate valves and valve sentries will shut protecting the integrity of the system. The power source will have a latching relay connected to the Modicon-PLC coils and will be used to turn the pumps on and off remotely

8.8 Detector and Heat Sinks Monitoring

The temperature measurement of the three detectors and eight heat sinks will be done using an AD592CN temperature transducer. The temperature transducers will affix

to the copper heat sink with Torr-Seal epoxy. The detectors will have the temperature transducers installed inside of a 0.3175 cm NTP board plug.

The current signal and power will be connected to the feedthrough through a 34-pin ribbon cable. The AD592CN, a two terminal monolithic integrated circuit temperature transducer that provides an output current proportional to absolute temperature. The AD592CN operates between -25°C and $+105^{\circ}\text{C}$. It has an accuracy of $\pm 0.3^{\circ}\text{C}$ and requires a DC power supply of between +4 and +30 Volts. The analogue current signal is sent to a shunt circuit, converting the current signal to an amplified analogue voltage signal (Figure 9.2).

The voltage signal then enters the Modicon-PLC through an ADC module in the N-4 vault.

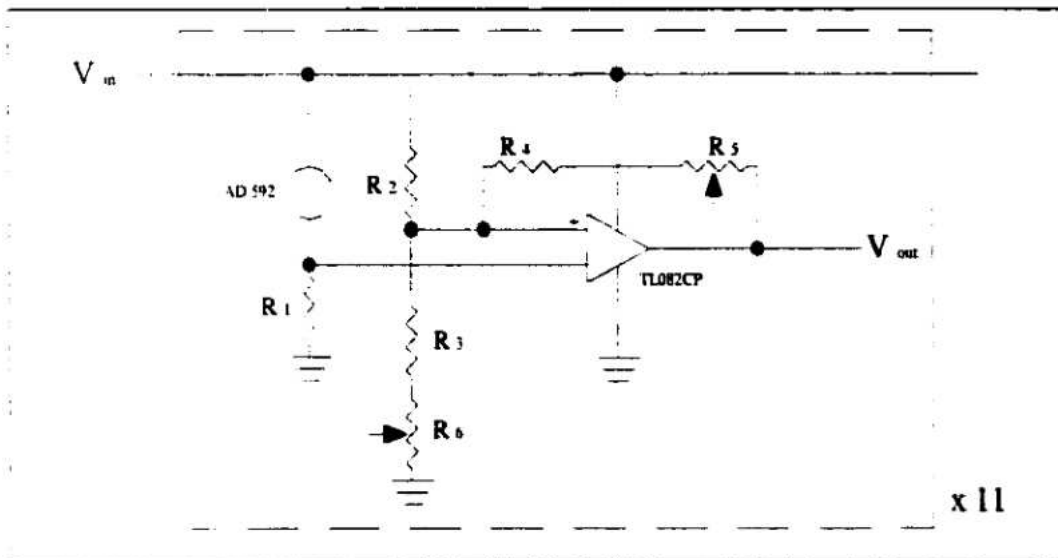


Figure 8.2: This figure represents a temperature transducer shunt circuit. There are 11 of them. Variable resistors are used for calibration and all use the same power supply. The output voltage signal is sent to an ADC, then to the Modicon-PLC where is read by the process control software. $R_1=10\text{k}\Omega$, $R_2=6.03\text{k}\Omega$, $R_3=1\text{k}\Omega$ to $500\text{k}\Omega$, $R_4=1\text{k}\Omega$ to $500\text{k}\Omega$.

8.9 Calibration Masks Motion Control

The only motion control in the FPD will be the two CRDC calibration masks. The rotary actuators operate digitally in and out and will be directly connected to the Modicon-PLC coils.

8.10 High Voltage Power Supplies

There are six channels of VME standard high precision high voltage power supplies and eight channels of PMT Base Integrated HV Supplies. All these modules will be controlled through the control system.

The VME crate used by the FPD will be split into a VME/EPICS crate with the addition of an Ether Net control module. This will allow control of the VME based systems to be done through the Ether Net rather than the data acquisition PC.

8.11 Interlocks

The FPD will have four interlocks that will cut the power to the high voltage supplies. The interlocks will be located at each access panel, and a "High Voltage On" warning light will be prominently located. This system of interlocks will be VME/EPICS based. It is being design and will be set up by ORCBS.

Chapter 9

Summary

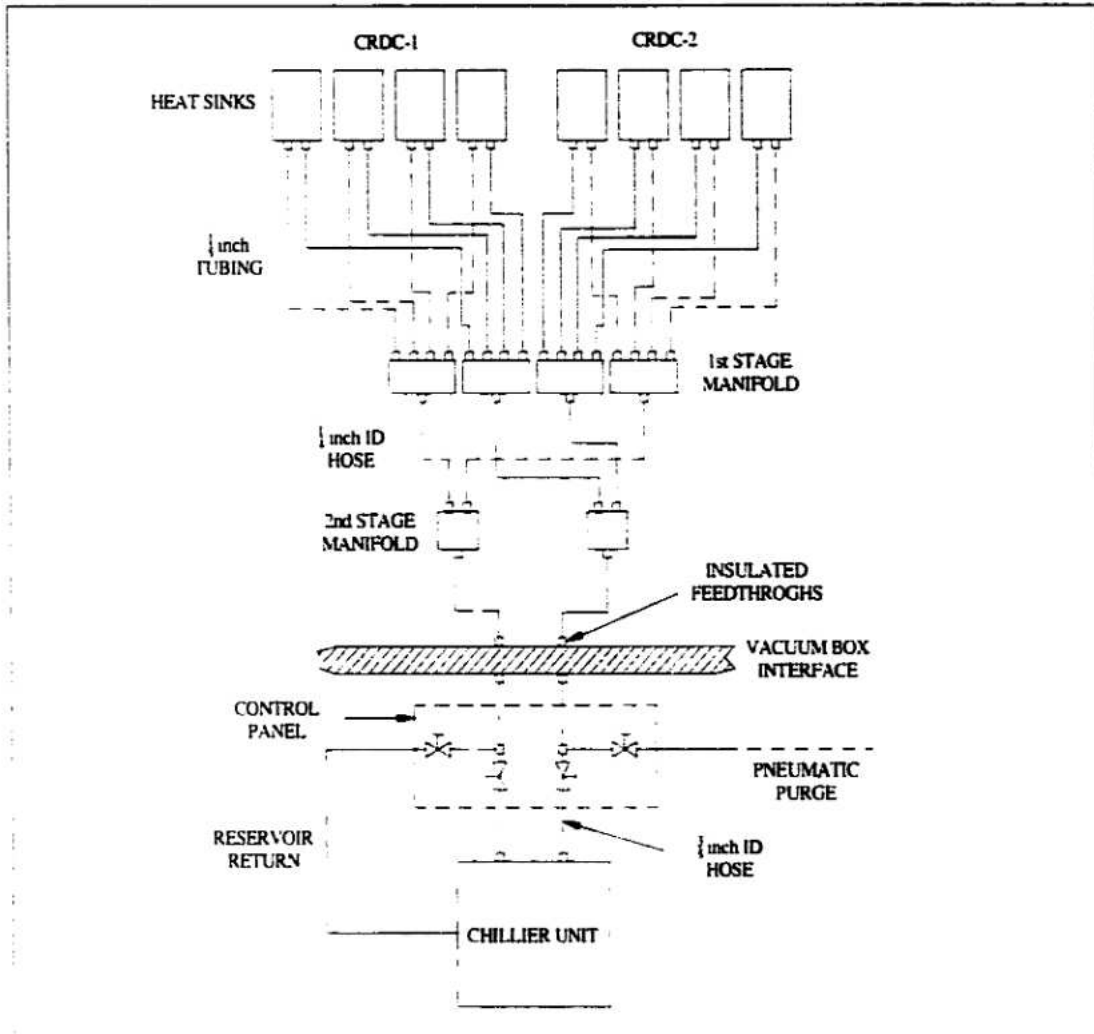
Excluding the actual construction of the focal plane detector there remains very little work to be done. All the components necessary have been, or are being fabricated. Nearly all the equipment has been ordered, and some has already arrived.

There are however, four details that still need to be addressed. First, the plate for the CRDC calibration masks needs to be designed and built. Second the electronics for the PMTs will need to be configured and purchased. This includes the CAEN Net VME modules and the integrated PMT bases. Third, the design and construction of the low voltage NIM module needs to start. Fourth, the feedthroughs for the temperature transducers, pressure transducers, and CAEN Net 9-pin connectors will need to be purchased.

With these components in hand, the assembly of the focal plane detector will be timely and effortless.

Appendix A

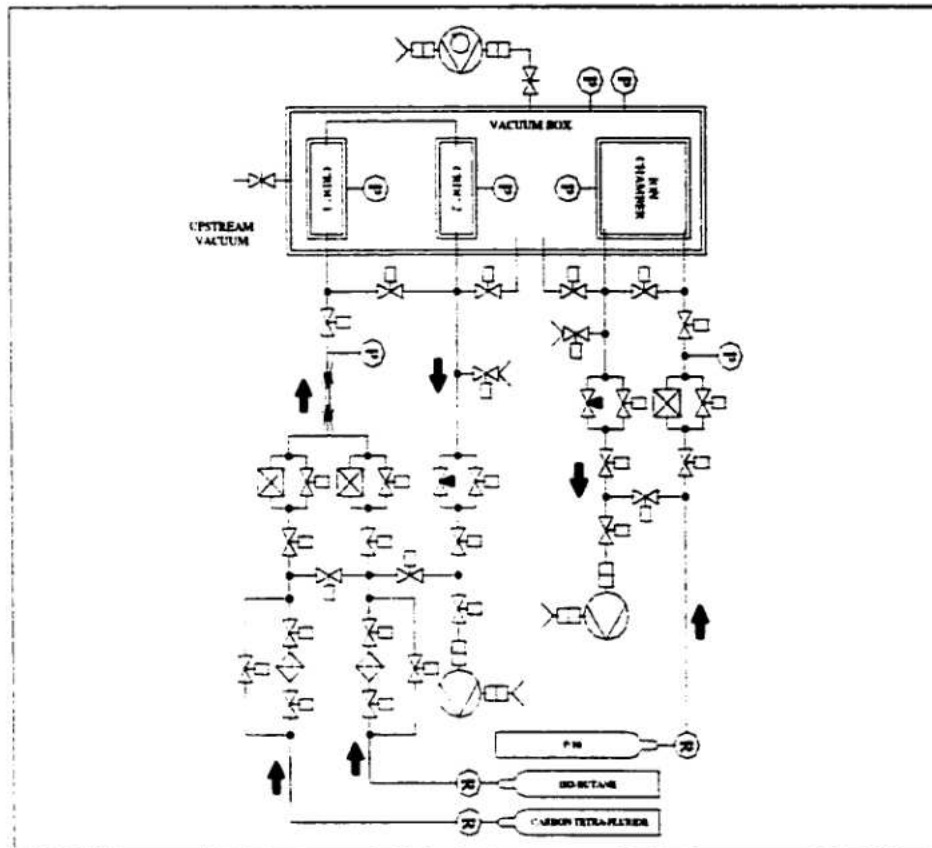
Cooling System Schematic



Appendix B

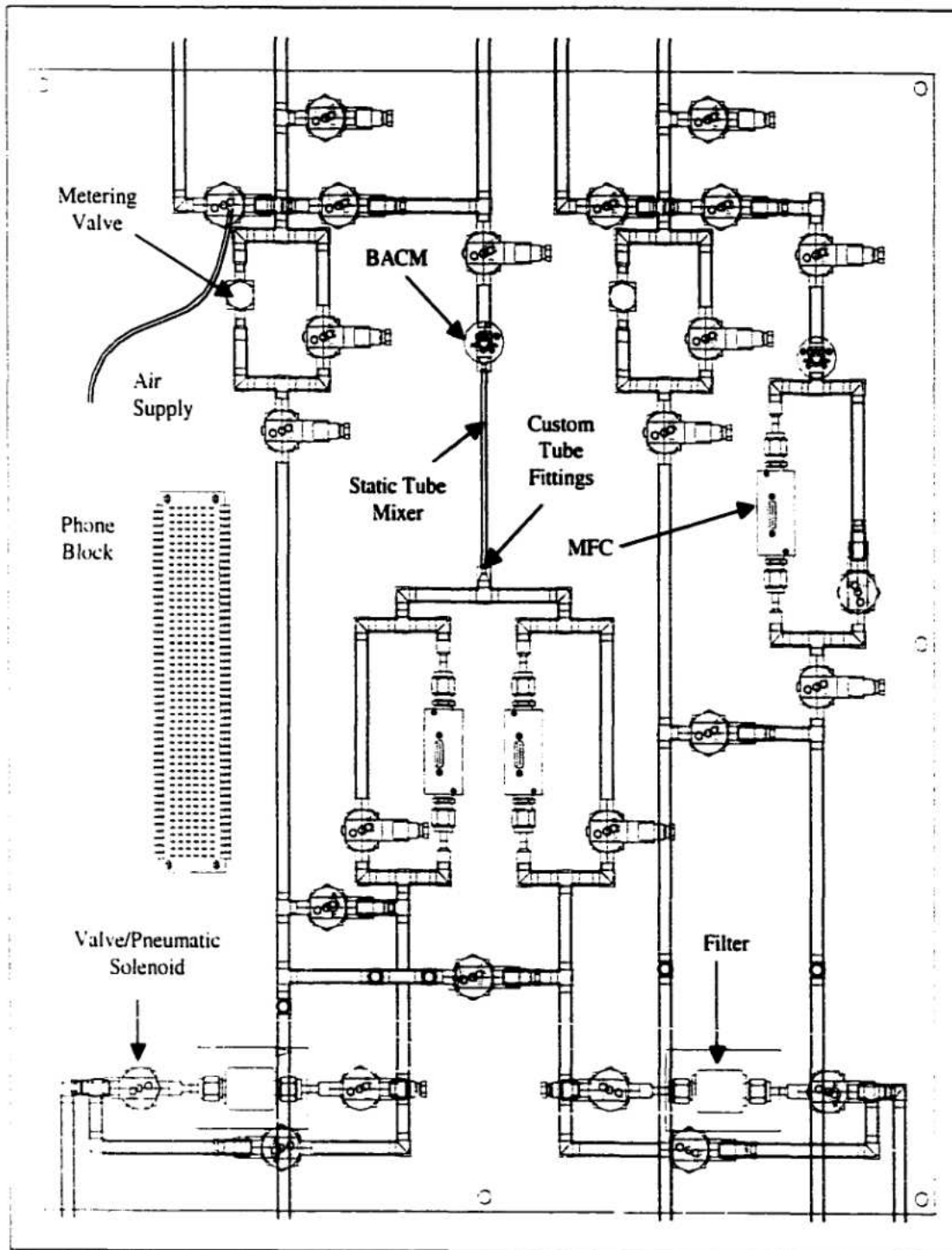
Gas system schematics

B.1 Gas system layout



Symbol	Representation	Symbol	Representation	Symbol	Representation
	Roughing-Turbo Pump		Metered Valve		Static Tube Mixer
	Roughing Pump		Pressure Transducer		Up To Air
	Mass Flow Controller		Regulator		Direction Of Flow
	Pneumatic Valves		High Purity Filter		
	Gate Valve		Oil Mist Eliminator		

B.2 Gas Handling System Control Box Layout



Layout inside of the Gas Handling System control box. The components are mounted to a panel that sits off the back of the box. Along with the fore mentioned components there are custom fittings for the static tube mixer and BACMs. The phone block will be the power relay for solenoids, the air supply provides in series the air for the actuators.